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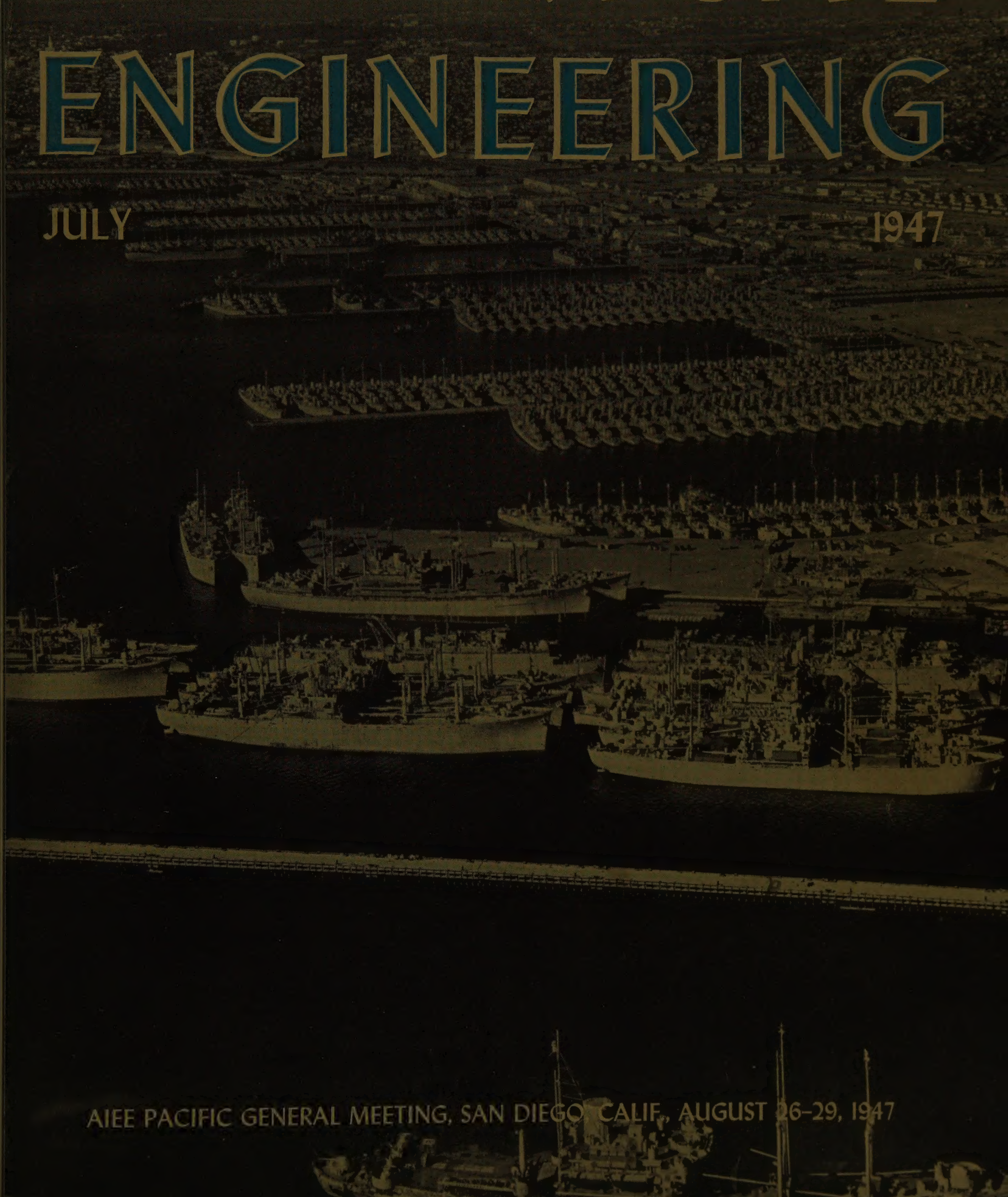
JULY 1947



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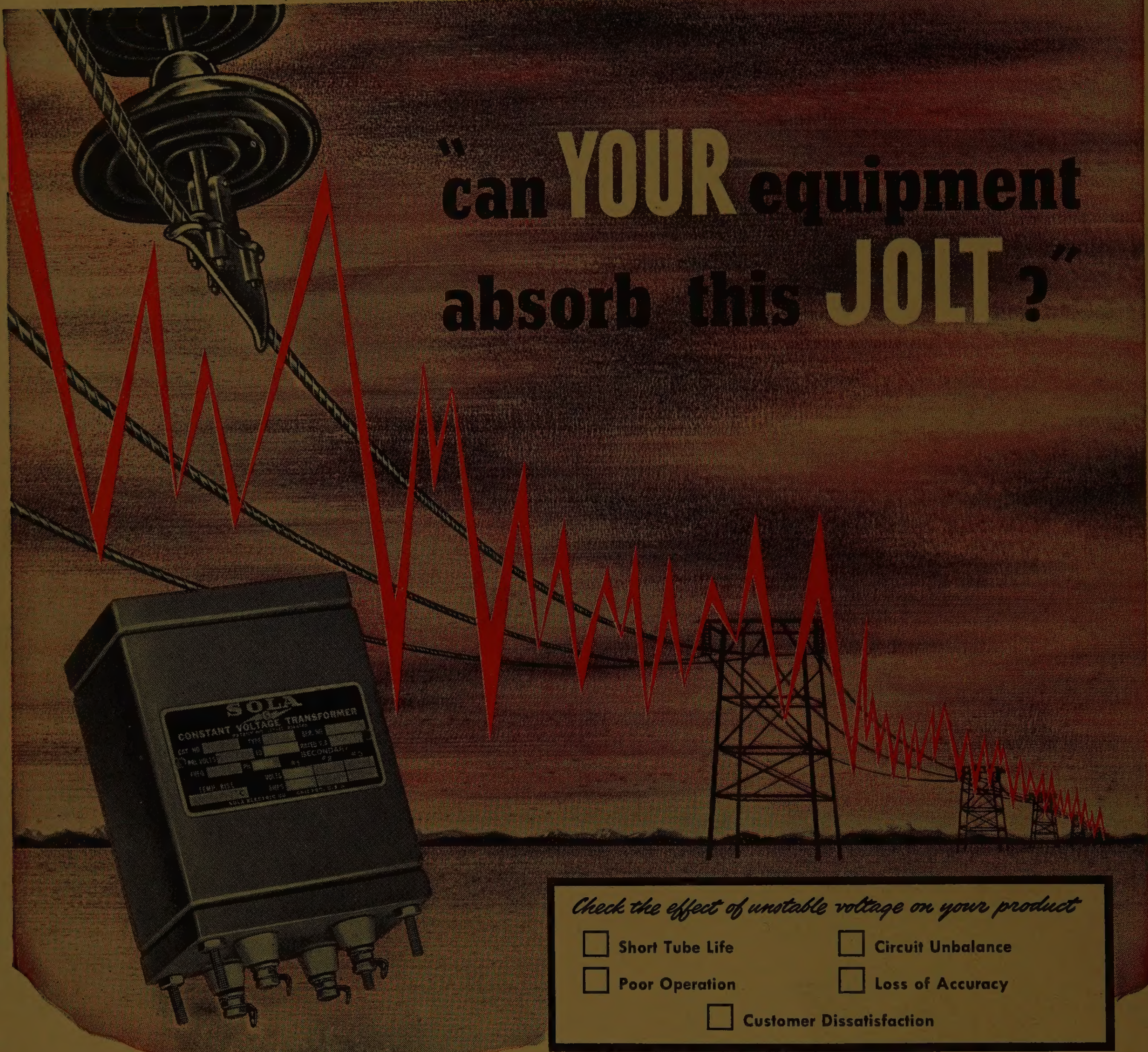
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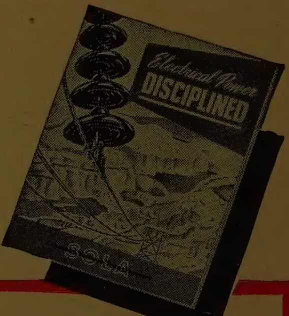

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1947

The Cover: Scene in San Diego Bay where more than 300 destroyers and auxiliaries are moored as an inactive reserve fleet by the United States Navy.

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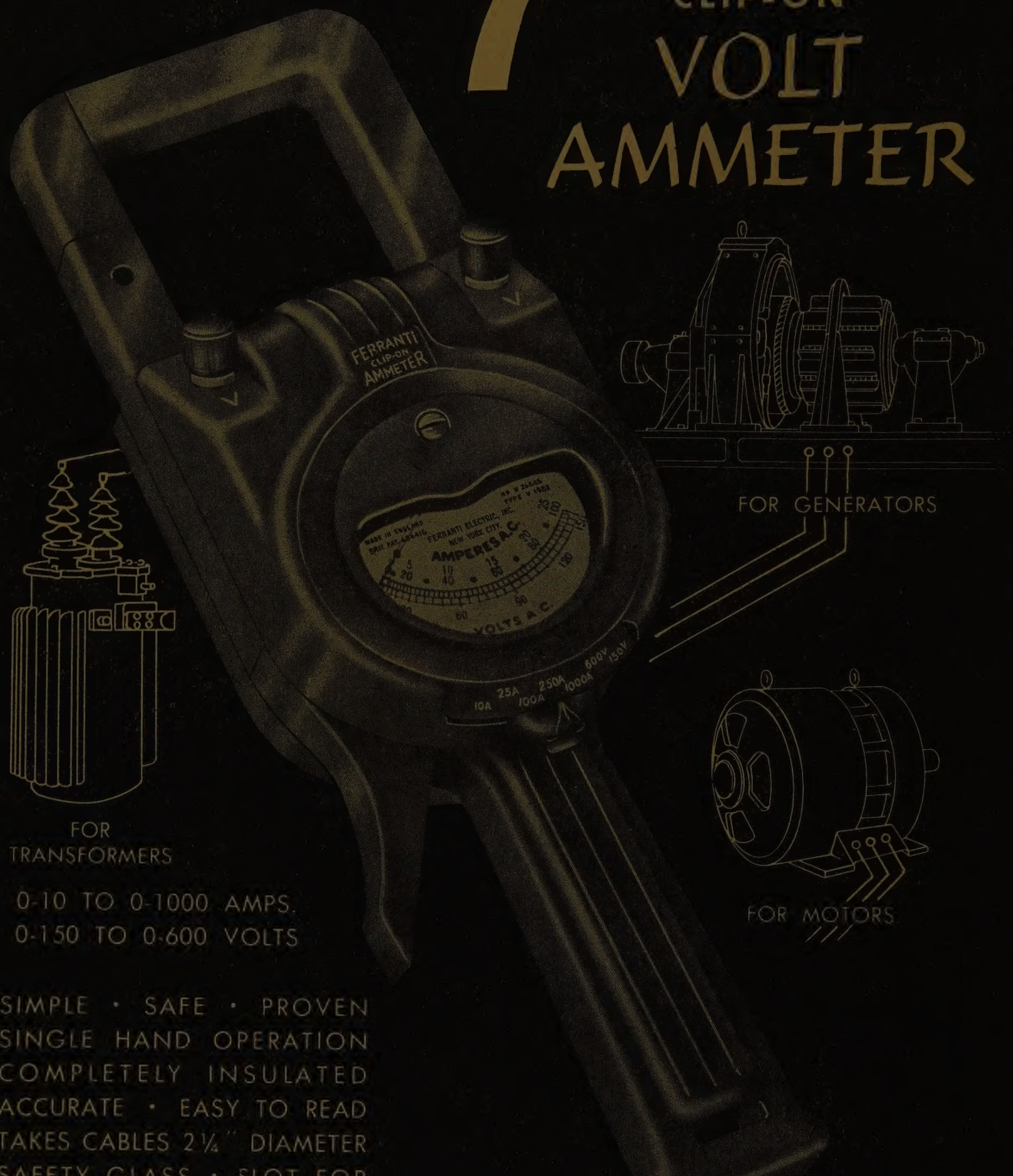

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Atomic Energy in Industry

H. A. WINNE
FELLOW AIEE

The potential value of atomic energy to industry is currently the subject of much speculation. An evaluation of the situation indicates that although atomic energy is not producing commercially useful power as yet, such production is technically possible. However, it is likely that by-products of atomic energy such as radioactive isotopes and fission products will prove of more immediate importance to society.

IN THE PRODUCTION of special materials, engineering, scientific, and industrial groups already have contributed much to the start of the atomic age. The transformation of the basic uranium to a degree of purity and form suitable for plutonium production in the Hanford Engineer Works is just one example. The production of graphite for the Hanford piles, sufficiently free of neutron absorbing impurities to allow a chain reaction with natural uranium, was a signal achievement. However, all that has been accomplished thus far represents just a beginning.

The use of materials in a nuclear chain reactor or "pile" involves consideration of their "nuclear properties."[*] Previous uses of engineering and construction materials have been based only on external physical and chemical properties. The addition of suitable nuclear properties to the list of requirements portends many changes from the engineering materials which have become common. The periodic table contains many elements whose possibilities as useful engineering materials never have been explored thoroughly because of such factors as scarcity, cost, and difficulty of processing. Many of these have attractive nuclear properties, but production methods for refining, reduction, alloying, and working, have not been developed. Beryllium is an example mentioned by Smyth[1] which is valuable as a moderator because of its low atomic weight. The production of metallic beryllium essentially free of neutron absorbing impurities is still almost a laboratory process.

The potential uses of atomic power plants for various special purposes such as ship propulsion, or for the provision of a source of power where none now exists, that is, supplementing present power sources, have been mentioned by many writers. However, atomic power development as a whole will be a long and difficult process.

The use of radioactivity and radiation in chemical and metallurgical fields has been possible on a very limited scale for a good many years. It has not been exploited widely, largely, no doubt, because of the scarcity and cost of radioactive elements. The development of atomic energy makes possible the production of radioactive isotopes of great variety and on a considerable scale. This, together with widespread interest and education in the fields of radio chemistry, radiation chemistry, and nuclear physics, should stimulate activity in using these unique and potent tools.

Atomic Power

As a preface to a discussion of the problems entailed by the use of atomic power, the following broadly reviews the operation of an atomic power plant.

Figure 1 shows schematically a possible atomic power plant. The heart of the plant is the nuclear reactor which generates heat by the conversion of mass to energy. The heat is converted to electric energy by extracting it from the nuclear reactor with a heat transfer fluid which boils water in a heat exchanger to make steam for a conventional turbine-generator.

The nuclear reactor must be surrounded by an adequate radiation shield to protect power plant personnel from lethal neutron, gamma, and other radiation. The heat exchanger and primary heat transfer fluid probably will need a moderate amount of shielding.

Into the nuclear reactor goes the atomic fuel, one of the known fissionable materials such as U235, and if it is desired to generate new fuel at the same time that the charged fissionable material is being consumed, a fertile material, such as U238, also may be charged. A material is called fertile when it can be transmuted to a fissionable material by the capture of neutrons.

Discharged from the pile are the partly burned fuel and the irradiated fertile material which contains some new fissionable material. Later use of the unburned fuel and the new fuel both require chemical separation from

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[*] "Nuclear properties" refer to properties such as those which make materials good for slowing down neutrons (moderator) or low in absorption of neutrons or suitable to withstand radiation of neutrons in a pile (radiation stability).

Essentially full text of an address presented at the AIEE North Eastern District meeting, Worcester, Mass., April 23–25, 1947.

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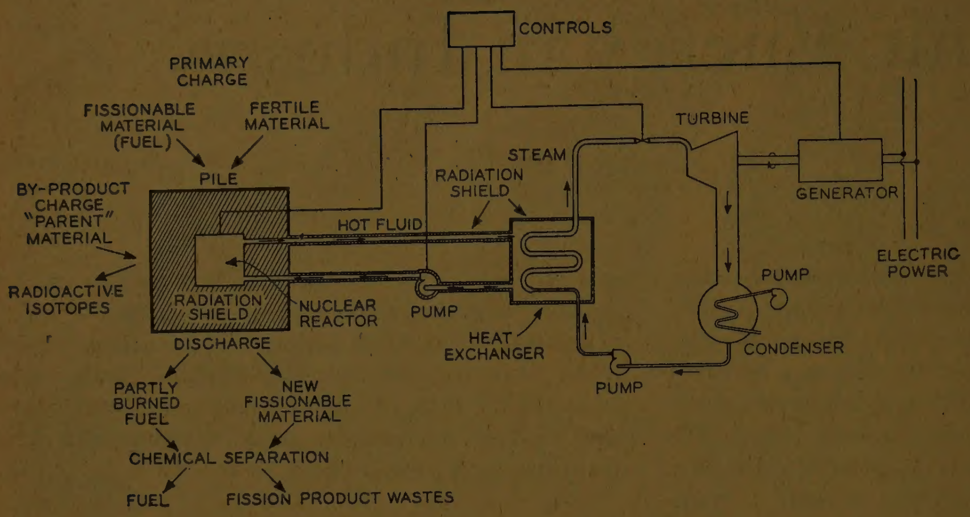


Figure 1. Schematic diagram of atomic power plant

any other structural materials, containers, and from the fission product wastes.

An optional phase of operation of an atomic power plant is the production of radioactive isotopes. This is shown in Figure 1 as the adding to the pile of a by-product charge of some "parent" material such as nitrogen, from which a radioactive isotope such as carbon (C14) is produced by the capture of neutrons.

PRINCIPLES OF THE NUCLEAR REACTOR

Occasion frequently may arise for reference to some of the nuclear principles of the chain reaction in the nuclear reactor. They are reviewed briefly in the following.

Energy is released by the fission of the nucleus of a fissionable atom, U235 for example. The two nuclear fragments vary in the number of protons and neutrons contained in each. In general, each fragment is the nucleus of a radioactive isotope of some element ranging from atomic number 35 to 65.

The two fragments fly apart with tremendous velocities. Their kinetic energy constitutes most of the energy released at the expense of a loss in mass of one thousandth of the original mass. The fragments will collide with adjacent atoms, giving up energy by increasing the vibration, amplitude, and velocity of the surrounding atoms. Such atomic agitation is recognized as the temperature of the material. Thus the energy appears almost immediately as sensible heat in the fuel itself and within a few thousandths of an inch from where the fission occurred.

Fission was caused by the capture of one neutron by the U235 nucleus. This neutron, when added to the 92 protons and 143 neutrons present, caused the group of particles to become violently unstable and to break immediately into the two unequal fragments.

The entering neutron was the trigger. It has been absorbed and now is lost to the process. If the reaction is to proceed at a constant rate, another neutron must trigger another U235 nucleus, and so on, at equal intervals of time in a continuous chain. The characteristic of U235 (and also plutonium Pu239 and U233) which makes it suitable for such a chain of fissions is that two to three free neutrons are released as part of the debris at fission in addition to the two main fragments. Thus there are available more than enough triggers for the next fission.

The fact that more than one neutron is released per fission permits some losses or nonprofitable absorptions of neutrons without killing the chain reaction (an obvious necessity in practice). The fact that on the average more than two neutrons are released per fission permits several choices in the use of the extra neutrons which are available in addition to the one required for a continuous constant-rate chain reaction. Of course, some of these extra neutrons escape from the reactor and are wasted in the shield or otherwise, but some can be put to useful purpose.

The extra neutrons can be used to expand the reaction, essentially doubling it at each generation. This may result in a bomb. They can be absorbed in a suitable material to produce radioactive isotopes for chemical, biological, or therapeutic use. Of most significance to power, however, is the use of these neutrons to make new fissionable atoms, for example, to transmute U238 to U239 which changes spontaneously to neptunium (N239) which, in turn, changes spontaneously to Pu239. Pu239 is a suitable atomic fuel. Every neutron which can be used in this way replaces the U235 atom burned with a new Pu239 atom and so helps to replenish the atomic fuel supply. Another example of fuel replacement is the production of U233 from thorium.

The neutrons in any nuclear reactor are valuable. Their loss or waste on reactions extraneous to the purpose of the pile is a permanent economic loss. Therefore, pile design for high neutron economy is important.

By controlling the neutron flux, the power output of the pile is regulated. To hold constant power level in a slow neutron pile, rods containing an excellent neutron absorber such as boron or cadmium may be inserted to absorb some neutrons so that equal numbers are available to produce fission at each generation. To increase power, the rods are withdrawn so that a small fraction of the excess neutrons is available at each generation to produce fission. The power then accelerates exponentially. It will continue to accelerate, except for variations in reactivity produced by temperature, expansion of materials, or change of their nuclear properties, until the control rods again are pushed in to absorb the excess neutrons. After the control rods are returned to an equilibrium position the reaction continues at a constant but higher rate. Power is reduced by the reverse of this procedure.

The time between one generation of the neutrons emitted instantaneously at fission (prompt neutrons) and the next generation is extremely short. This is true even in slow neutron piles where each neutron is forced to lose almost all of its energy by a multitude of collisions with the light nuclei of the moderator before the next fission. The time is so short that acceleration, even with small changes in reactivity, would be too fast for the control mechanism to be effective were it not that about one per cent of the neutrons is not emitted promptly at fission, but is delayed from 0.01 second to a minute or more. The delayed neutrons provide a time constant of exponential acceleration long enough to permit control, provided the excess reactivity never is allowed to exceed the margin of delayed neutrons.

The fission products include many radioactive isotopes which give off quantities of very intense radiation, and some of them continue to do so for thousands of years. Provision may be made to contain them within the fuel. If some are allowed to emigrate from the fuel they must be prevented from entering the heat transfer fluid, or else the fluid system must be designed to handle the accumulated radioactive isotopes.

All of the materials in the pile are subject to high neutron and gamma or X rays which may affect chemical and physical properties. Furthermore, almost all pile materials will become radioactive in greater or lesser degree after extended operation.

DEVELOPMENT OF AN ATOMIC POWER PILE

A scientist or engineer, observing the principles and associated properties of a nuclear reactor, is forced to recognize a number of fields in which extensive research and development work must be done to facilitate the design and construction of a high performance atomic power system.

First, perhaps, a high performance system should be defined. Considering land-based plants, proposed primarily for power, a prime consideration is economic use of fissionable materials, including replacement of burned fuel by transmutation. Second, losses in the transformation of heat to electric energy, for instance, should be as low as the current knowledge of materials and processes will allow. This requires temperatures as high as practicable.

Considering how the energy is released, one recognizes that the heat first must be removed from the body of the fuel to its surface. This may entail thermal stresses. It certainly involves a knowledge of the thermal conductivity of the material, and its stability and strength after a reasonable percentage of the atoms have disintegrated into a wide variety of pairs of new atoms. The percentage of the fuel which can be consumed before it must be removed and reprocessed will depend on these factors and also on the neutron physics of the pile because, in general, as the fuel undergoes fission, and the fission products accumulate, the pile reactivity will decrease. The frequency of reprocessing, including its cost and the accompanying losses, may have a profound effect on the economic use of fissionable material.

Such fuel problems cannot be solved by simply consulting a handbook. The metallurgy of fissionable materials is a new and only partially investigated field. Possible alloys and mixtures include many metallic elements which may be valuable because of low absorption of neutrons but which are comparatively new to the metal processing industries. Conversely, many well-known alloy or mixture components have high neutron absorption and are not suitable. The fuel designer may wish to consider ceramics to obtain very high temperature. If he decides to prevent fission products from contaminating the heat transfer fluid, he also must develop a suitable barrier between the fuel and the fluid. This barrier cannot be a heat barrier, so bonding or joining techniques, again using materials which are stable under radiation and which do not absorb too many neutrons, will need investigation. As emphasized by the Smyth Report, this barrier or "canning" problem turned out to be one of the most difficult to solve for the Hanford piles.

Just to develop a fuel which will function in the pile is not enough. The effect of fuel assembly materials on the cost and efficiency of the chemical reprocessing plant must be considered. As the whole pattern of atomic power plants, fuel supply facilities, and fuel reprocessing facilities develops, national and international security may require centralized reprocessing plants. Standardization of fuel elements also may be a factor. The mechanical form of the fuel preferably should permit charging to and discharging from an active pile, storage and transportation of the radioactive fuel packages with suitable protection for personnel, and so forth.

The purpose of discussing the problems of fuel design so extensively has been to emphasize the many detailed but important research and engineering problems which must be solved on just one component of a high performance pile. Related problems must be solved on almost all components. The fact that achievement of the probable vast benefits of atomic power entails an integrated and orderly solution of a multitude of problems hardly can be overemphasized. Furthermore, these problems include factors new to design engineers, only recently introduced in scientific research, such as:

1. Material stability under radiation, including physical, chemical, electrical, and thermal properties.
2. Neutron absorption characteristics of materials.
3. Effect of contamination within the body of the materials by transmutation and fission.

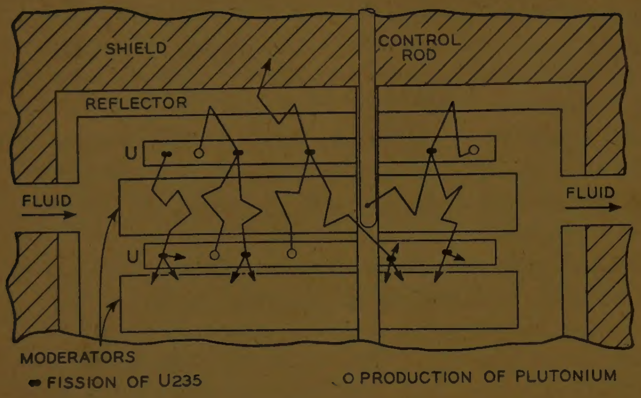


Figure 2. Schematic structure of uranium pile

Finally, the experimental techniques for determining many of these nuclear properties of materials are relatively new, some are difficult, some approximate, and in most cases the experimental facilities currently are very limited.

It is important to remember too that in the design of the fuel package, and in fact in the design of all parts of a pile, reliability must be achieved to a degree which transcends most of our experience. This is the result of possible radiation hazards from failures, and the extreme difficulty of inspection and repair of a "hot" (in the radioactive sense) pile.

In addition to the problem of fuel design, there are many other features of a nuclear reactor for power purposes which pose some nice questions for engineers and scientists. These are not necessarily less important or difficult than the fuel problems, and involve many of the general considerations and details mentioned in the foregoing. Some of these are reviewed briefly in the following paragraphs.

Heat Transfer Fluid. The selection of a fluid to carry the heat from the nuclear reactor to the heat exchanger in which it may be converted to steam or a hot gas is a vital matter. Gases, liquids, and liquid metals all must be considered. The medium must have low neutron absorption. It must be reasonably stable under intense radiation. It must have, of course, good heat transfer characteristics, must be noncorrosive, preferably nontoxic and nonexplosive. Availability and cost also are important.

If the medium is to be allowed to boil in the reactor, then the neutron absorption characteristics of the vapor must be approximately the same as those of the liquid. Otherwise a sudden flashing to vapor of a part of the liquid might result in such a sudden change of nuclear characteristics in the pile that the control mechanism could not compensate for it.

Radiation Shield. The shield for protection of personnel from the lethal neutron and other radiations is an absolutely necessary part of any power pile. If research and development can reduce considerably the volume and weight of shield required, it will be very helpful in facilitating the application of atomic power plants to ships, and elsewhere where weight and size are of great importance.

Control. The reliability of the control system must be absolute, so that any failure must result in safety rather than permit a runaway. It must be able to handle all possible variations in reactivity of the pile, either normal or accidental, gradual or fast, such as result from the slow consumption of the fuel, or the sudden loss of part or all of the heat transfer fluid. It must be effective at all times, under any possible set of conditions. It must make it impossible for the "nuclear boiler" ever to explode. These requirements are rigid, and *must be met.*

AN ATOMIC POWER SYSTEM

Of what factors might the land-based atomic power system of the future be comprised? In all of the discussion on the subject the fact is implicit that at present no possibility is foreseen for obtaining usable electric power directly from an atomic pile. The atomic energy will appear as heat which, when converted into steam or hot gas, will feed conventional turbogenerators. In other words, from the steam supply pipe on to the consumer the system will be similar to present systems using coal or oil. The nuclear reactor and heat exchanger, however, will replace the boiler. There will be involved components comparable in function to present fuel and ash transportation, storage, preparation, and disposal installations, but vastly more important from economic and security points of view.

The system may include both "primary" and "secondary" reactors. By a primary reactor is meant one which produces not only power, but fissionable material as well. The reactors currently operating at Hanford, inasmuch as they produce heat (at present dissipated in the Columbia River) and plutonium, are by this definition primary reactors. Under the international control plan proposed by the United States to the United Nations such reactors would be under the control of an international authority.

By a secondary reactor is meant one which consumes but which does not produce fissionable material. If the fuel charged into such a reactor is "denatured" so that it could not be converted easily to bomb use, the international control plan would permit such a reactor to be under national or private authority.

The system would include a chemical reprocessing, or fuel reclamation, plant. When the fuel in the reactor has reached a certain state of depletion, it will have to be removed and passed through a remote-controlled shielded process for removal of the fission products, and put into suitable form for further use. Here again the international control plan would require operation by the international authority because of the possibility of diversion of atomic fuel.

It is obvious that consideration of national and international security will have a large bearing on how such operations will be conducted, how fuel will be stored and transported, even on geographical location of plants.

Here again there are many factors which will have a profound effect on future developments, factors which today cannot be evaluated with any degree of accuracy.

ECONOMICS OF ATOMIC POWER

Treatment of the subject of the economics of atomic power has been placed after the preceding discussion purposefully. Estimates of economy and cost of atomic power sufficiently accurate to predict where or when or if atomic power will be in competition with other fuels do not appear feasible in view of the multitude of unknown technical and economic factors which will be established only as research and engineering produce results. However, the long-term future prospects for competitive and economic atomic power look bright. The magnitude of the potential ultimate gains to society are so great that research and development must proceed vigorously on a wide front.

The following quantitative statements can be made with a considerable degree of accuracy.

As an atomic power station or system will be similar to a coal or oil-fired station in all parts from the turbine steam pipe on to the consumer, the investment and operating costs for this part of the station will be essentially the same as for coal or oil.

The nuclear reactor and heat exchanger in an atomic plant probably will have a somewhat higher first cost than the boiler installation in an ordinary steam plant. Thus it is probable that an atomic plant's opportunity for reducing cost of power to the consumer lies in the cost of fuel only. In modern public utilities, cost of fuel represents, on the average, only about 20 per cent of the total cost of power to consumers, so atomic power can affect only this percentage of the total cost to the consumer.

Some of the significant unknowns, or unavailable data, which make it impossible to estimate accurately the over-all cost of atomic fuel today are first cost of atomic fuel in suitable concentration and form; cost and efficiency and frequency of chemical extraction, reprocessing, and final preparation; plus waste disposal; all of which are ultimately chargeable to the consumer. Also included, but on the credit side, are the gains from sale of radioactive tracers, by-products for research, and use of facilities for test and research. These latter gains are estimated by the Carnegie Endowment Committee on Atomic Energy[2] to be small compared with revenue from power. Another unknown factor is the extent to which the national or world interest may require the production of fissionable material by national or international authority for any reason, and perhaps regardless of cost. In this event, atomic power is a by-product and its production and sale at competitive rates simply replaces expense for cooling otherwise required by such installations and pays for some, perhaps all, of the cost of the plant and its operation.

APPLICATIONS OF ATOMIC POWER PLANTS

There has been much speculation, some of it unwarranted, as to possible uses of atomic power.

The heavy protective shielding required on any such plant precludes its use where extremely light weight is required. The shield would crush an automobile or a truck. Atomic power on inhabited aircraft is extremely unlikely, at least for a long time.

It ultimately may prove possible to design an atomic plant for a locomotive, although it does not look feasible at present.

Atomic plants for naval and large commercial ocean vessels appear definitely possible, and also attractive from the standpoint of making refueling extremely infrequent. This well may be the first real commercial application.

Atomic power plants for land use certainly are feasible technically, and probably will be attractive first where fuel is scarce and high in cost.

Thus far this article has been devoted to a discussion of power as distinct from industrial uses and benefits of other aspects of atomic energy, tracer chemistry, radiation chemistry, and so forth. These are reviewed more briefly in the following. Such emphasis should not be construed as an opinion that power is any more important to industry. Other benefits may prove more important in the generations yet to come; current estimations of the time that must elapse before any authoritative evaluations can be made range all the way from 10 to 40 years.

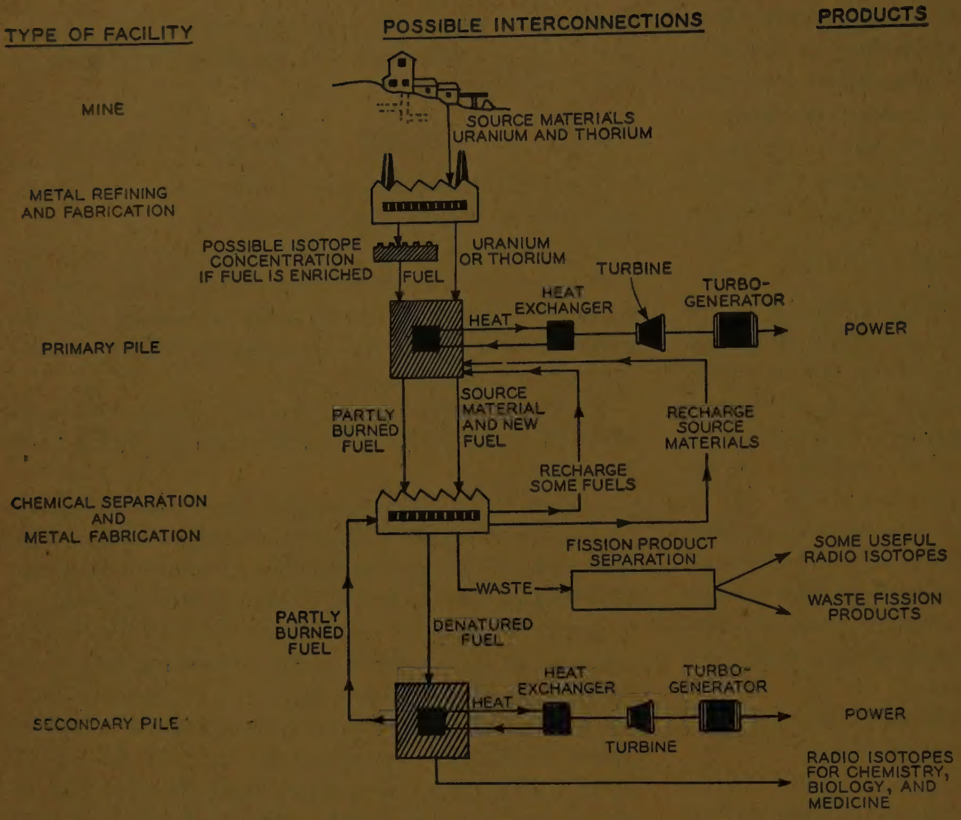
Radioactivity and Radiation

In discussing the following phases, the authors have drawn much upon published material,[2–4] particularly the predictions of future possibilities in these fields by such authorities as Doctors Arthur H. Compton, Zay Jeffries, James Franck, and Milton Burton.

INDUSTRIAL USE OF RADIOACTIVITY

The prime characteristics of radioactive tracers which make them of value are two. First, extremely small quantities can be detected by registering the particles or radiations emitted at each disintegration on a suitable radiation detection instrument. Second, by the same means it is possible to detect and to measure the amount of tracer present quite accurately without removing it from the compound by chemical separation or even without removing or sampling the compound from its process container.

Perhaps the surest widespread industrial uses are in the chemical laboratories. Because chemically and physically the radioactive isotope of an element acts


TYPE OF FACILITY
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PRODUCTS
MINE
SOURCE MATERIALS URANIUM AND THORIUM
METAL REFINING AND FABRICATION
POSSIBLE ISOTOPE CONCENTRATION IF FUEL IS ENRICHED
FUEL
URANIUM OR THORIUM
TURBINE
HEAT EXCHANGER
TURBO-GENERATOR
HEAT
POWER
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PARTLY BURNED FUEL
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TURBO-GENERATOR
HEAT
POWER
SECONDARY PILE
TURBINE
RADIO ISOTOPES FOR CHEMISTRY, BIOLOGY, AND MEDICINE

Figure 3. Atomic power facilities

exactly the same as the stable isotope of the same element, analytical techniques can determine the amount of a given element in the final product or at an intermediate stage if a known amount of radioactive isotope of that element is added to the bulk at the start. This can be of value when quantitative analysis or spectrographic methods cannot be used.

Some of the scientific advice given to the United Nations Atomic Energy Commission by the Office of the United States Representative, which has not received wide national circulation, is quoted:[3]

> The availability of a variety of radioactive tracer elements will afford possibilities for answering questions hitherto difficult to answer. By the use of instruments sensitive to radioactivity, the radioactive atoms of a given element, which always travel with their nonradioactive brothers, may be used as indicators of the travel of the latter, a phenomenon often difficult to follow by ordinary methods. Particularly important are questions as to how, and how fast, atoms transfer from one molecule to another or from one place to another in the course of a chemical process, including such processes as corrosion, diffusion, absorption of molecules on surfaces, and formation and destruction of colloids.
>
> The use of radioactive tracer atoms holds much promise for the study of the composition of liquids and vapors in equilibrium with each other, and for studying the performance of distillation columns and other equipment used in chemical engineering, for example, in the oil industry. Particularly important as a tracer in the oil industry and wherever carbon compounds are concerned will be the carbon isotope C14.
>
> The radiations from the fission chain reaction are capable of inducing chemical reactions which cannot ordinarily be carried out, since one effect of radiation is a sort of catalysis of thermodynamically possible reactions.
>
> METALLURGY
>
> In metallurgy, the use of radioactive tracers has many possible applications. Some of these are as follows:
>
> 1. Diffusion of an element into itself and into alloys in which it is a component could be followed if the diffusing atoms are radioactive.
> 2. Inclusions could be identified by adding a radioactive form of a suspected component to the melt and photographing by microradiographic techniques.
> 3. Positive identification and location of minor constituents, which often markedly affect the properties of metals and alloys, could be made by microradiographic methods; such information is usually very difficult to obtain by microscopic methods.

The previous discussion has envisaged adding the radioactive tracer to the material. A very different analytical technique is based on producing radioactivity in all susceptible elements of a sample by subjecting the sample to a known amount of radiation in the neutron flux of a pile. Then the presence of minute traces of impurities can be identified by observing the half-lives and type of radioactive emanations after removal from the pile. The amount of impurity also can be estimated.

Tracers may find widespread use in production processes. Here, however, additional limitations enter. Cost in repetitive use becomes more significant. The Carnegie Endowment Committee on Atomic Energy[2] estimated that for radioactive carbon (C14) to be attractive to industry, it should be produced at about $500 per gram to reach mass use in petroleum, coal tar, and similar large volume production. This assumed that a milligram (50 cents) could tag a ton of material at an additional cost of 50 cents for incorporating the tracer in the process, making the total cost $1 per ton. The 1946 price of C14 from the Manhattan District was about $400,000 per gram.

The committee estimated that the market might pay about $10,000 per gram for C14 used in bulk organic chemicals, and $100,000 per gram for use in pharmaceuticals.

Actual use, however, may develop unexpected advantages, and of course cost is bound to decrease as production increases.

Another critical problem in production as distinct from laboratory use is the question of widespread distribution of all types of products and materials containing traces of radioactivity and the effect on sensitive materials such as photographic film, and on living things as a result of continual intimate exposure or possible ingestion by unwarned people or animals. Some believe that this problem will limit production uses to those isotopes with short half-lives of perhaps a few days. Then a period of storage of products before shipment could eliminate virtually all radioactivity. Such considerations may limit the list of possible tracers. For example, C14 has a half-life estimated at 6,000 years. Two other carbon isotopes, C10 and C11, have impractically short half-lives of 8 seconds and 20 minutes respectively. Thus no carbon radioactive isotope is known which could be used if radioactivity of the product is objectionable. Such questions can be settled only as experience and knowledge is gained and when proposed uses are specific rather than hypothetical. The need for elements with short half-lives either in production process or laboratory well may require a wide distribution of isotope production facilities near industrial and population centers.

It is also possible that experience will show that the amount of radioactivity required for tracer purposes in many products is so small that long-half-life tracers can be used widely in metallic, organic, and other materials. Then industry may be faced with radioactivity in materials purchased for further processing, in scrap for remelting, and so forth. Such background radioactivity, if not controlled, might interfere with the further use of tracers. Thus in years to come materials specifications may be found containing minimum tolerances for radioactivity.

The number of industrially important elements for which potentially useful radioactive isotopes, those with half-lives longer than a half day, are not known is quite limited but includes oxygen, nitrogen, magnesium, aluminum, and silicon.

There are some production uses which do not require presence of the radioactive isotope in the product. Included are separation processes where the radioactive isotope is one of the elements rejected, also processes involving catalysts.

For example, in some oil refining processes, a catalyst is diffused through a reaction vessel. Certain malfunctions may cause it to segregate or to emigrate from the vessel. If the catalyst were tagged with a radioactive isotope, its concentration and location could be registered continuously through the walls of the tank.

RADIATION CHEMISTRY

The infant field of radiaton chemistry relating to the use of radiation to produce or catalyze chemical reactions is perhaps too new to warrant extending speculation very far. However, the use of ultraviolet radiation to produce vitamin D in ergosterol is a well-known and related reaction.

Doctors Franck and Burton[4] have examined the possibilities and reported to the United Nations the following "groups of processes where application of radiation chemistry appears promising:"

> We may anticipate economic advantages in the vast field of polymerization processes which are now so successfully applied in the manufacture of plastics, rubber, and so forth; in this field, in fact, initial successes already have been obtained. In a similar connection, studies even prior to the war on the effects of radiation on some of the constituents of natural gas indicate that they may be converted, via the medium of radiation chemistry, into industrially important products. Their present uses (for example, in the production of carbon black or for fuel) are economically unsound. Related to such processes in a certain sense is the low-temperature cracking of oils, which should be intensively studied. Radiation chemistry here presents the opportunity of a new technique which may produce new and very interesting products.
>
> A host of rare but medically important drugs, until now synthesized only by plants but not *in vitro* (in the test tube) probably will be by-products of the utilization of radiation chemical processes. Very interesting preliminary photochemical effects on viruses have been reported; viruses may be made to lose their virulence while still retaining their ability to produce antibodies. Progress in this important field is limited by the lack of penetration and the specificity of the rays which must be used; radiation chemistry should promote such work at an accelerated pace. The chemical aspect of the large field of biologicals is a portion of the field of radiation chemistry which we are now just beginning to tap. Some notion of the vistas which lie before us, when we begin to understand primary effects a little better, is indicated by the suggestions of the medical use of specifically absorbed radioactive dyes and of the possible large scale production of vaccines.
>
> In the fields of inorganic chemistry and physics the production of new phosphors and of inorganic polymers should be studied. Possible hardening of metals by radiation and a host of new enterprises made possible by the interesting process of dislocation of atoms in solids may become important.

In this field, chemists point out that often, when a reaction is discovered by the use of radiation, continued investigation leads to thermal or catalytic means to make the reaction "go". In general the latter are much cheaper for production. Such progress does not, however, minimize the significance of an original discovery using radiation to produce the reaction.

In the field of such ultracomplex molecules as antibiotics such as penicillin and streptomycin new and improved strains often are cultivated from mutations. Radiation may be a tool which can produce a variety and extent of mutations in such molecules of many times the diversity and rate at which they occur in normal evolution.

Chemists may learn much about the stability of chemical bonds by breaking them with alpha, beta, gamma, or neutron radiations. While such radiations have been known for many years, they have been available only in the form of a few rare natural radioactive materials or in connection with the limited output of "atom smashing" accelerators. The vast spectrum of radiation intensities now beginning to become available makes widespread research in these fields possible.

FUTURE POSSIBILITIES

A great many of the statements in this article of necessity are hedged with "if", "but", "possibly", or "probably". This fact merely emphasizes the newness of the field under consideration and the tremendous possibilities ahead.

Atomic energy is not producing commercially useful power as yet, although such production is technically possible. It is probable that one or more experimental or demonstration plants will be in operation within the next two to four years.

Such production appears economically feasible, at least for many special applications. However, the development of economically competitive atomic power promises to be a long-term project, possibly requiring decades. And its advent will be gradual. It is the author's belief that atomic power will supplement, but not supplant, present power sources.

What may be termed the by-products of atomic energy—radioactive isotopes, radiation chemistry and metallurgy, fission products—well may prove of more importance to society than atomic power itself, and many of their benefits probably will be realized more quickly.

It is quite evident that in order to reap all the potential benefits, a tremendous amount of research and development must be carried on. There is no doubt but that it will be done.

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The Physics of Electronic Semiconductors

G. L. PEARSON

The band theory of solids is capable of explaining such fundamental properties of electronic semiconductors as the dependency of specific resistance on impurity content, the negative temperature coefficient of resistance, the sign of the Hall and thermoelectric effects, and the direction of rectification. Measurements of the specific resistance and the Hall constant enable the calculation of density, mobility, and mean free path of the electric carriers as a function of temperature and impurity.

SEMICONDUCTORS have a number of unique properties which make them useful in the design of electric circuit elements. Their electrical resistivities near room temperature fall in the range 10^{-2} to 10^{-6} ohm-centimeters. In comparison, the resistivities of typical metals in this temperature range are around 10^{-5} ohm-centimeters and those of insulators between 10^6 and 10^{15} ohm-centimeters or higher. The electrical resistivities of semiconductors and insulators decrease rapidly with rise in temperature, while those of metals increase relatively slowly. The resistivities of dry rectifiers, which consist of a metal in contact with a semiconductor, may change by a factor of 1,000 as the sign of the applied potential is reversed.

Semiconductors may be classified on the basis of their current "carriers" into electronic, ionic, and mixed conductors. In ionic and mixed conductors, ions are transported through the solid, thus changing the composition of the material. As this leads to unstable characteristics, only those substances in which the current is carried solely by electrons will be discussed here.

As early as 1900 P. Drude suggested that the high electrical conductivity of metals was due to the large number of "free" electrons. In the modern theory of semiconductors and insulators as proposed by A. H. Wilson around 1930, it is shown that most of the electrons in these substances are bound to their respective atoms, thus leaving only a small fraction of the electrons (1 per 10^3 to 10^9 atoms) free to conduct current. Furthermore, the number of such electrons increases rapidly with in-

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Essential substance of paper **47-34**, "The Physics of Electronic Semiconductors," presented at the AIEE winter meeting, New York, N. Y., January 27–31, 1947, and scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

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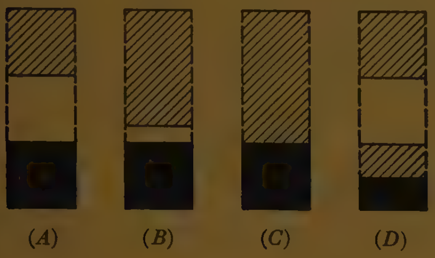
crease in temperature, thus accounting for the high negative temperature coefficient of resistance in semiconductors and insulators.

The physical picture of a metal consists of an electron gas formed by the free electrons in which the positive ions float. As the ions repel each other, they tend to arrange themselves so as to use their space to the best advantage, which requires that they take up some close-packed crystal arrangement such as body-centered cubic, face-centered cubic, or a close-packed hexagonal arrangement.

BAND THEORY OF SOLIDS

If all of the charge in the electron gas were free to move through the lattice under the influence of an electric field, diamond and magnesium should be equally good conductors—however, this is not the case. This was one of the major problems of the physics of solids which had to wait until the advent of quantum mechanics around 1930 for a solution. Although the problem is now completely solved, the solution is so wrapped up in mathematical language that it cannot be presented here. It can be said that solids, like free atoms, are pictured as having a large number of discrete energy states with one and only one electron allowed in each individual state. These energy states arrange themselves into bands, the structure of which determines the properties of the solid. Just as automobiles in a parking lot are unable to move when they are parked bumper to bumper, so the electrons in a solid are immobile when every energy state in the bands is filled with an electron. When there are unoccupied states in the band, the electrons move under the action of an electric field and the material is a conductor. A semiconductor has only a few electrons in a conduction band (a band with energy states only partially filled) at room temperature, but this number increases with increase in temperature.



A—An insulator
B—A semiconductor
C—A metal with overlapping filled and conduction band
D—A metal with half-filled band

The clear regions are forbidden, the dark areas allowed and full, the shaded areas allowed but empty

Figure 1. Energy level diagrams for solids

These ideas are represented graphically in Figure 1. The width of the forbidden region may vary from zero to ten electron volts. Figure 1*A* indicates the conditions existing in an insulator where all the electrons are in filled bands and the forbidden region is so wide, several electron volts, that thermal agitation is incapable of exciting electrons from the filled band into the conduction band. In a semiconductor (Figure 1*B*) the energy gap between the filled and conduction bands is small, one electron volt or less, so that electrons from the completely filled band may be thermally excited to the conduction band, thus producing a conductivity which increases with temperature. In some metals such as magnesium, the energy gap between the filled and unfilled bands is zero as shown in Figure 1*C*, and in others such as the alkali metals the lower band is only half filled with electrons (Figure 1*D*). In either case conduction is good at any temperature.

SEMICONDUCTOR CLASSIFICATIONS

More detailed representation of the electron arrangements in the energy bands of chemically pure semiconductors and of those containing small amounts of different types of impurities are shown in Figure 2. Figure 2*A* is for pure semiconductors which have been termed intrinsic.

At any temperature T an average number n of electrons are excited thermally from the lower filled band to the upper band. Conduction then can take place both by means of the electrons in the upper band and holes in the lower band, which is now not quite full. In the latter mechanisms the sign of the carrier charge appears to be positive.

In most semiconductors the conductivity is highly dependent on the impurities present in the sample. By impurities we mean added foreign atoms, physical defects in the lattice, or differences from stoichiometric composition. It is assumed that the impurities introduce extra energy states in the normally forbidden region between the bands as shown in Figures 2*B* and 2*C*. Electrons in these impurity states are localized in the neighborhood of the impurity and cannot take part in conduction. Two types of impurity are possible. In the donator or *N*-type shown in Figure 2*B* the impurities carry extra electrons with them and usually have energies near the conduction band. Since the energy gap E_1 is much less than E, electrons are thermally excited at lower temperatures than in an intrinsic semiconductor. At very low temperatures the extra electrons are all bound to the impurity atoms; at higher temperatures these electrons are thermally excited to the upper band where they may conduct.

A—Intrinsic semiconductor
B—N-type impurity semiconductor
C—P-type semiconductor

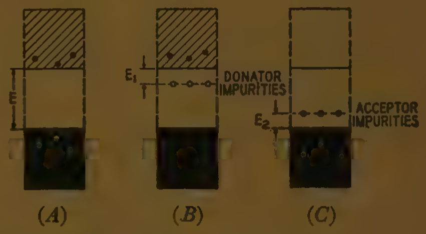


Figure 2. Energy level diagrams for semiconductors

At still higher temperatures the donator electrons may all become excited so that the number of conduction electrons remains constant with further increase in temperature until the thermal energy becomes great enough to excite intrinsic electrons from the lower band. An impurity semiconductor turns into an intrinsic semiconductor at high temperatures. At low temperatures the number of excited impurity states and, therefore, the conductivity at a given temperature increase with the amount of impurity present.

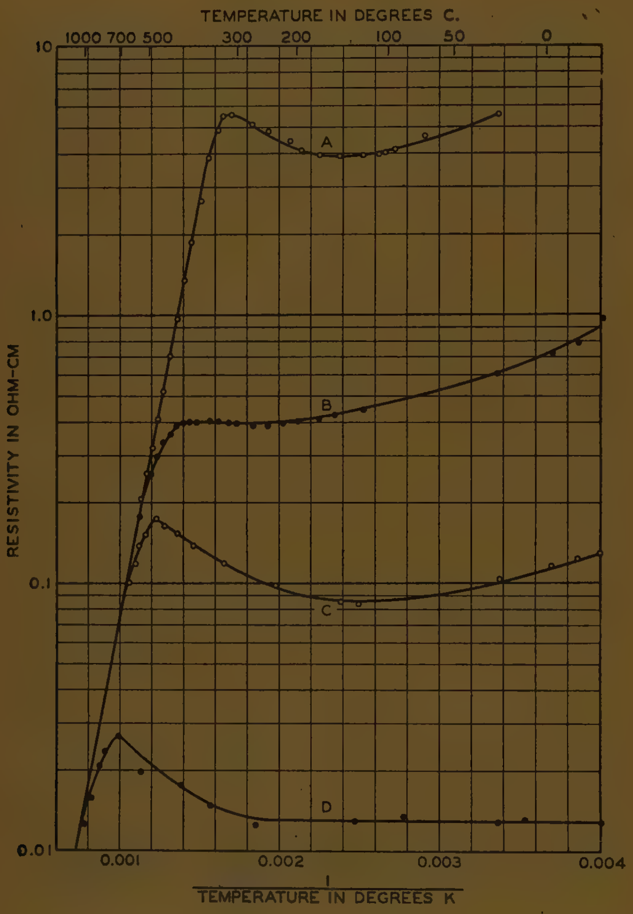


Figure 3. Logarithmic plot of resistivity as a function of inverse absolute temperature

A—"Pure" silicon
B, C—Silicon plus unknown impurities
D—"Pure" silicon plus 0.03 atomic per cent of boron

In the acceptor or *P*-type impurity semiconductor shown in Figure 2*C*, the extra states lie near the filled band. At very low temperatures these states are all empty, but on heating, electrons from the lower band are excited into them. Although the excited electrons are bound, hole conduction is found possible in the lower band.

In an intrinsic semiconductor the conduction is by an equal number of electrons and holes, in an *N*-type conduction is solely by electrons at low temperatures and by electrons and holes at high temperature, and in a *P*-type solely by holes at low temperatures and by electrons and holes at high temperatures. In addition to explaining the magnitude of the conductivity and temperature coefficient, we will see that this picture clarifies certain anomalies in the Hall and thermoelectric effects in semiconductors.

ELECTRICAL RESISTIVITY

Wilson's theory shows that for intrinsic semiconductors the specific resistance ρ in ohm-centimeters is

$$\rho = A\epsilon^{E/2kT} \tag{1}$$

where A is a factor which varies relatively slowly with temperature, T is the temperature in degrees Kelvin, k is Boltzman's constant (8.69×10^{-5} electron volts per degree), and E is the energy gap between the two bands in electron volts. From equation 1 it can be seen that a plot of $\log_e \rho$ versus $1/T$ for an intrinsic semiconductor should give a straight line the slope of which is equal to $E/2k$ or $5{,}750E$ in electron volts. Figure 3 is such a plot for silicon containing different amounts of impurity. At the higher temperatures the resistivities of all the samples fall on the same straight line in accordance with the picture of semiconductors in the intrinsic range. The slope of this line indicates that the energy gap between the filled and unfilled bands in silicon is 1.2 electron volts. In the branch curves, the number of intrinsic electrons and holes becomes small compared with the number excited from impurity states and the resistivity is determined by the amount of impurity present. The decrease in resistivity just beyond the branch point is not associated with a change in the number of excited impurity states, but rather arises from a decrease in mobility resulting from the heat motion of the ions in the lattice.

On going to still lower temperatures the impurity resistivity increases and an estimate of the energy gaps E_1 or E_2 can be made from the slopes. Although sample A is the purest silicon we know how to prepare, even this material must contain some impurity, as defined above.

Resistivity measurements such as those shown in Figure 3 have been made on other materials which have intrinsic characteristics. The values of the energy gap E in electron volts are shown in Table I. Diamond, of course, is an insulator at ordinary temperatures but it, like most other insulators, has a high negative temperature coefficient of resistance and shows intrinsic characteristics at very high temperatures.

The values of the energy gaps E_1 and E_2 due to impurities can be deduced in like manner from measurements made at low temperatures.

PHOTO EFFECT

In addition to an increase in conductivity with rise in temperature, many semiconductors show increased conductivity on exposure to light of the proper wave length. This arises from the fact that just as electrons can acquire enough energy thermally to excite them from the filled band to the conduction band, so they may acquire sufficient energy optically to produce the same result.

The fundamental equation giving the energy of a quantum of light is

$$E=\frac{hc}{\lambda} \tag{2}$$

where E is the energy in electron volts, h is Planck's constant (4.1×10^{-15} electron volt per second), c is the velocity of light (3×10^{10} centimeters per second), and λ is the wave length of the optical radiation in centimeters. The energy of a light quantum in electron volts according to equation 2 is 1.236 divided by the wave length of the radiation expressed in microns. Thus, only wave lengths shorter than 1.05 microns have energy equal to or greater than the 1.2 electron volt energy gap in intrinsic silicon. Light longer than this wave length should pass through silicon without absorption but shorter wave lengths should be absorbed and cause photoconductivity.

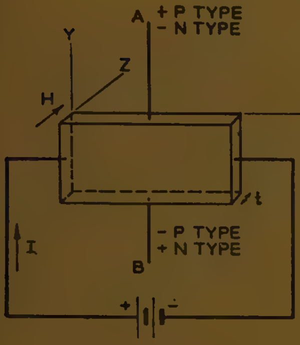


Figure 4. Schematic circuit arrangement for the measurement of Hall coefficient in semiconductors

THE HALL EFFECT

In 1879 Hall discovered that a potential difference may be produced across a strip of metal which is carrying a current by placing the strip in a magnetic field. Consider a rectangular plate in the plane $Z=0$, with edges parallel to the X and Y axes as shown in Figure 4. If a current I from an external battery flows in the X direction and the sample is placed in a magnetic field H in the Z direction, a transverse electric potential V is produced between the terminals A and B. The magnitude of this potential in volts is given by the equation

$$V=\frac{10^{-8}RIH}{t} \tag{3}$$

where I is the current in amperes, H the magnetic field in gausses, t the thickness of the sample in centimeters, and R represents the Hall coefficient in centimeters cubed per coulomb.

The Hall effect occurs because the magnetic field causes the electrons in the sample to travel in curved paths, thus charging up the sides of the conductor until a transverse electric field exists of just the right magnitude to cancel the effect of the magnetic field and make the electrons travel through the solid undeviated. Under the conditions shown in the figure, the terminal A should be negative with respect to terminal B. In many metals and semiconductors this is the case, but in others the sign is reversed. The so-called anomolous Hall effect (reversal of sign in some materials) was not understood until the advent of Wilson's band theory of solids and semiconductors.

In the light of this theory, N-type samples give the correct sign since conduction is by free electrons in the upper band but P-type samples give the reverse sign as conduction is by holes (equivalent to an electron with a positive charge) in the lower filled band.

The number n of free electrons or holes per cubic centimeter in semiconductors can be deduced from Hall measurements because the theory shows that

$$n=\pm3\pi/8eR \tag{4}$$

where R is the Hall constant in centimeters cubed per coulomb, e is the electron charge (1.59×10^{-19} coulomb), the minus sign is for electrons, and the plus sign for holes. Putting in the values of the constants we find that n is equal to 7.4×10^{-18} divided by R.

The conductivity σ of an electrical conductor is given by

$$\sigma=nev \tag{5}$$

where n is the number of current carriers per cubic centimeter, e is their charge, and v their mobility in centimeters per second per volt per centimeter. Combining equations 4 and 5 we see that the mobility of the holes or electrons in a semiconductor is

$$v=\frac{8R\sigma}{3\pi}$$
$$=0.85R/\rho \tag{6}$$

In intrinsic semiconductors where electrons and holes are both present at the same time, the Hall coefficient is the following

$$R=-\frac{3\pi(n_1C^2-n_2)}{8e(n_1C+n_2)^2} \tag{7}$$

where n_1 is the electron density, n_2 the hole density, and C the ratio of the electron mobility to the hole mobility. As C is generally greater than one, intrinsic semiconductors show the negative sign.

The value of the mean free path of the current carriers is shown from the theory to be

$$l=\frac{2\times10^{-7}R(2\pi mkT)^{1/2}}{\pi e\rho} \tag{8}$$

where l is the mean free path in centimeters, M is the mass of the carrier ($m=9\times10^{-28}$ grams for electrons and is assumed to be the same for holes). Or

$$l=3.5\times10^{-10}T^{1/2}R/\rho \tag{9}$$

At room temperature the mean free paths of silicon samples C and D are, respectively, 4×10^{-7} and 2.3×10^{-7} centimeter. These are approximately 10 times greater than the lattice constant of silicon which is 5.4×10^{-8} centimeter.

THE THERMOELECTRIC EFFECT

When a semiconductor is connected between two metal wires as shown in Figure 5, a thermoelectric voltage is produced when the junctions are at different temperatures. The sign of the potential is dependent on whether the semiconductor is N- or P-type. Intrinsic semiconductors give the same sign as N-type. The thermoelectric power for some semiconductors may be as high as one millivolt per degree centigrade, which is greater than that obtained from most metal thermo-junctions by a factor of 200.

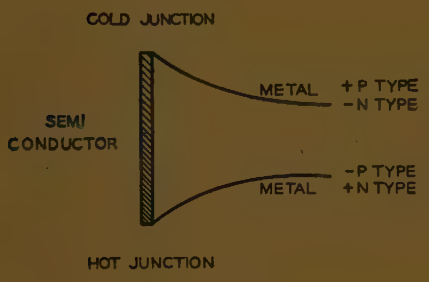


Figure 5. Schematic circuit arrangement for the measurement of thermoelectric power in semiconductors

For pure hole or pure electron conduction the magnitude of the thermoelectric power Q in volts per degree centigrade difference in temperature between the junctions is

$$Q=\frac{k}{e}\left[\log_e n/T^{3/2}-\frac{\log_e 2(2\pi mk)^{3/2}}{h^3}\right]$$
$$=(6.3\times10^{-4})-(8.6\times10^{-5}\log_e RT^{3/2}) \tag{10}$$

RECTIFICATION

When a metal point is placed against an impurity semiconductor, the combination has a nonlinear current versus voltage characteristic and acts as a rectifier. For a P-type sample the current is large when the semiconductor is made positive and the metal point is negative, but is small when these polarities are reversed. For an N-type sample the sign of the effect is reversed so that the current is large when the semiconductor is negative. Electrons which are thermally excited from the filled band to the acceptor impurity levels produce positive holes in the filled band and charge the acceptor centers negatively.

The positive holes in the contact area drift away, thus leaving next to the metal a negatively charged barrier layer from 10^{-6} to 10^{-4} centimeter in thickness. This barrier layer is a region of high resistivity so that when an external voltage is applied between the metal point and the back electrode, almost the entire drop is across the layer. If the external voltage is poled to make the semiconductor negative, the barrier layer increases in thickness and the resistance goes up. If the semiconductor is made positive the barrier layer becomes thinner and disappears entirely for a sufficiently high applied voltage. This is the direction of low resistance and high current. The case of an N-type semiconductor in contact with a metal is analogous. When electrons are thermally excited from donator levels to the conduction band, the donator levels are left positively charged. Electrons are depleted from the boundary layer, leaving an excess of positively charged donators. A positive external voltage applied to the semiconductor increases the thickness of the barrier and a negative voltage decreases the thickness, thereby permitting a large flow of current.

Table I. Values of Energy Gap E

Material	E in Electron Volts
Diamond	7
Boron	2
Cuprous oxide (Cu_2O)	1.4
Silicon	1.2
Germanium	0.76

THERMISTORS

Thermistors, or *therm*ally sensitive re*sistors*, are circuit elements made of semiconducting materials whose electrical resistances vary rapidly with temperature. The semiconducting materials used in the construction of thermistors include sintered mixtures of nickel oxide (NiO), manganese oxide (Mn_2O_3), and cobalt oxide (Co_2O_3). These semiconducting materials are unique in that small changes in their composition and impurity content have relatively little effect on their electrical characteristics. This is a particularly useful property as it permits the large scale manufacture of a reproducible product. It must be pointed out, however, that the energy band picture of solids is not applicable to these thermistor materials as each of the ingredient oxides have partially filled conduction bands like the metals of Figure 1D and therefore, according to the band theory, should be metallic conductors. This fundamental discrepancy was first pointed out by DeBoer and Verwey. Although these authors have derived a theory different from that of Wilson to explain the electrical properties of this class of materials, it will not be discussed in this article.

Electric Eddy Current Machinery

J. B. WINTHER
MEMBER AIEE

The electromagnetic dynamometer and slip-coupling units are a valuable aid in many motor applications. Though of relatively recent development this machinery has found application in the automotive industry, aircraft testing, ship propulsion, and with punch presses.

WITHIN the past decade research has brought to the foreground the "eddy current" slip coupling and dynamometer about which little has been written. Previously, eddy currents always had been considered a detrimental influence on the efficiency of rotating machinery which produced only heat losses.

The slip clutch (or slip coupling) is a device for transmitting torque through electromagnetic fields. There is never any mechanical contact between driven and driving members. This is in direct contrast to the magnetic friction clutch in which the magnetic force is used to clamp the two parts of a friction clutch together. Figures 1 and 2 show the fundamental slip coupling. In air-cooled units the driving member *A* is provided with fins for increasing ventilation. The driven member *B* is a toothed steel rotor with the center grooved to accommodate a toroid coil to which d-c excitation is supplied through two slip rings. No provision for cooling *B* is necessary because no eddy currents are generated in it and coil excitation is very low. As the driving member rotates at a slightly greater speed than the driven member, eddy currents are set up by the voltage induced in the drum which can be likened to the movement of an infinite number of parallel conductors through a magnetic field. The eddy currents travel across the area above the pole and at the pole axis are perpendicular to the direction of rotation. Their path is completed by returning in the open area in the region of the drum above the gap, between the teeth of the field member. Because the open area on each side of the tooth is utilized, a north and south eddy current pole is formed simultaneously. A like pole reacts against the main field pole while the unlike eddy current pole, which is the leading eddy current pole, forms the path of least reluctance. As can be seen from Figure 3, the magnetic field emanating from the field poles is crowded toward the leading edge of the pole by the action of the north and south eddy current poles. The torque is created by the effort of the armature to elongate the lines of flux and is a function of the current in the coil and the rate of slip. Because the eddy voltage generated is a function of the rate of cutting of the field flux by the armature, the strength of the eddy current pole increases as the slip increases. However, a limit is reached as the magnetic saturation point of the iron path is approached. This can be seen in the family of curves of Figure 4.

The torque has a tendency to level off as the slip speed increases because the angle of displacement between the eddy current and field pole increases as shown in Figure 3; as slip speed increases, the demagnetization also increases for a given value of excitation.

Some interesting results have been obtained by copper plating the armature surface facing the field poles to a thickness of about 0.010 inch. The addition of copper increases the air gap which is a disadvantage, but increases eddy current conductivity, resulting in a very steep characteristic curve at low slip. The unit then has a lower slip loss at full speed but at higher slips the torque is less because of higher armature reaction.

RECENT DEVELOPMENTS

To obtain the advantages of both the salient-pole and the finger-pole principle, the monocoil and fingered side plates are used to give the conventional finger pole construction and the salient pole feature is obtained by extending the fingers along the air gap and above the field coil beyond the center of the coil almost to the opposite ring. This portion of the tooth is rectangular and is staggered from the opposite plate to provide interlocking of the teeth as shown in Figure 7.

The effect then is an alternate north and south pole in the center of the armature. At minimum slip the salient pole has its most prevalent effect and the load may be brought very close to synchronism. As the rate

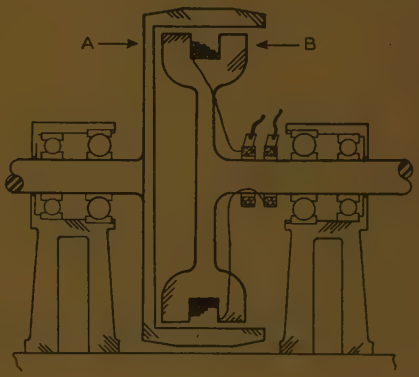


Figure 1. Sectional view of a typical clutch

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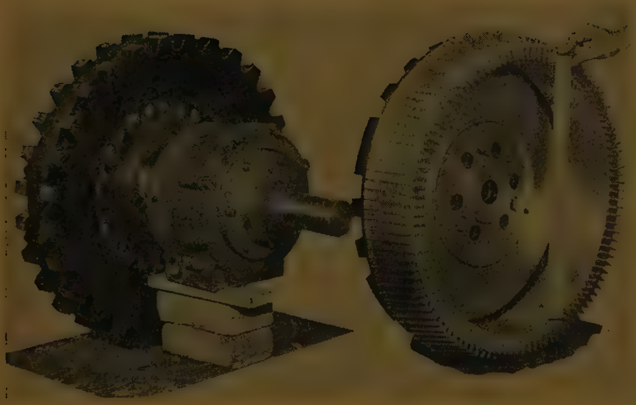


Figure 2. Clutch field and armature

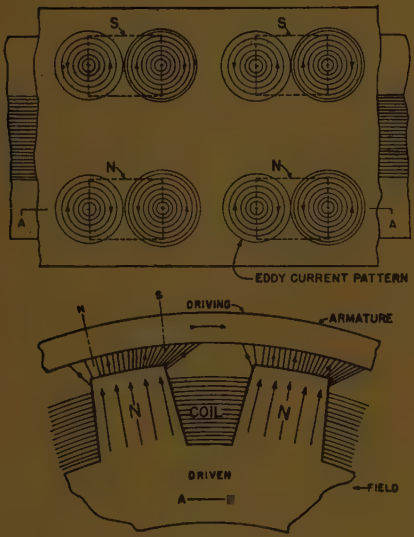


Figure 3. Eddy current and flux pattern

of slip is increased, armature reaction has a demagnetizing effect on the pole tips and forces the pole flux to emanate into the drum (armature) near the edge of the drum thus creating a finger pole effect, and thereby giving the finger pole (Figure 5) characteristic at speeds above which the salient pole ceases to function effectively.

For larger sizes the field member can be made into multiple sections as shown in Figures 8 and 9.

DYNAMOMETERS

One type of dynamometer (Figure 10) has its field coil in the eddy current member (the stator). Thus, the disadvantages of slip rings and brushes are eliminated. Also, there are no rotating field coils or inductor bars. The rotor teeth are shaped like those of a plain-toothed gear and run axially or lengthwise along the rotor. The rotor is a cast member requiring machining only for the air gap and shaft bore. Because it seeks the path of least reluctance the flux follows the rotor teeth just as though the rotor had the field coil (Figure 11.)

Where speed control is a consideration, a small d-c compound-wound self-excited shunt generator with rheostat control of field often is used. The field winding of the dynamometer is two independent coils. The generator, which is mounted on the dynamometer, is belt-driven from the main shaft. It supplies excitation to one coil, and the other is supplied from a fixed line voltage, the current being varied by rheostat control. The characteristic curve of the dynamometer then is made steeper since a change in speed results in a change in electrical output from the exciter generator. The control can be made even sharper by employing an electronic type of speed control. The electronic unit is the one which always is used on the high speed units as described hereinafter.

For high-speed testing machines the armature is rotated within the field. The field coil and field poles are on the stator because centrifugal force is too great for the conventional tooth to support itself at high speeds. The armature can be a solid steel cylinder, or where low inertia is desired, the rotor can be a hollow steel cylinder.

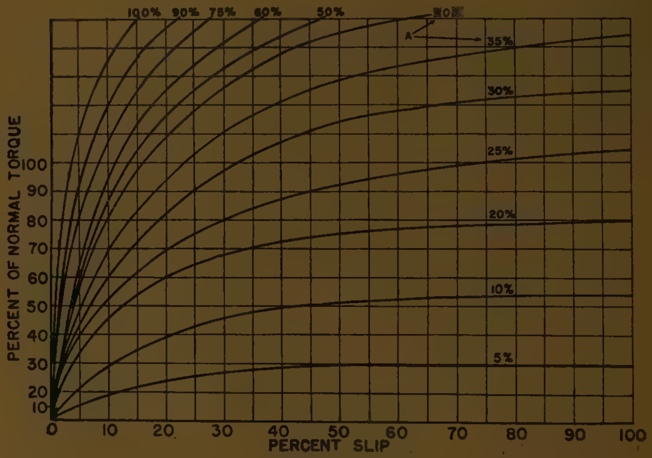


Figure 4. Torque–slip curves for Figure 1

A—Per cent of full excitation

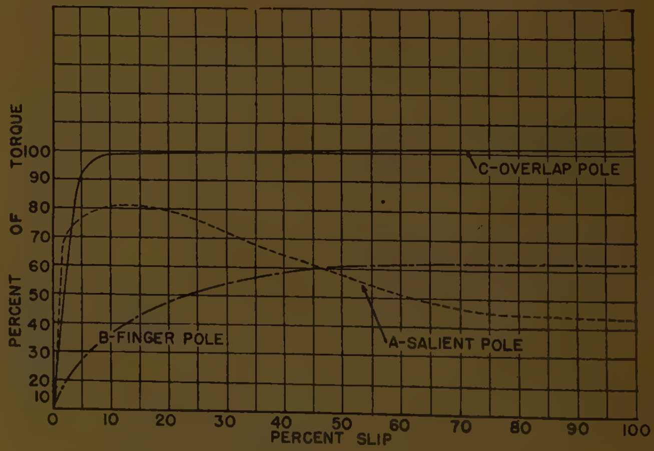


Figure 5. Comparison of characteristic curves

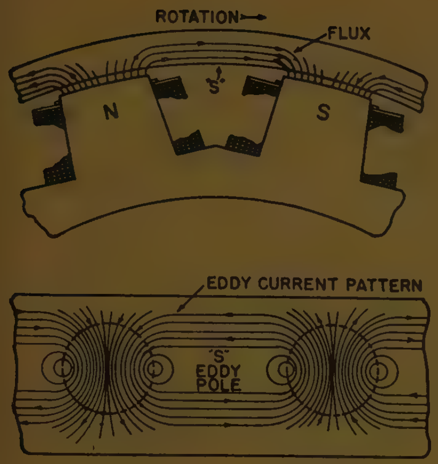


Figure 6. **Salient pole flux and eddy current pattern**

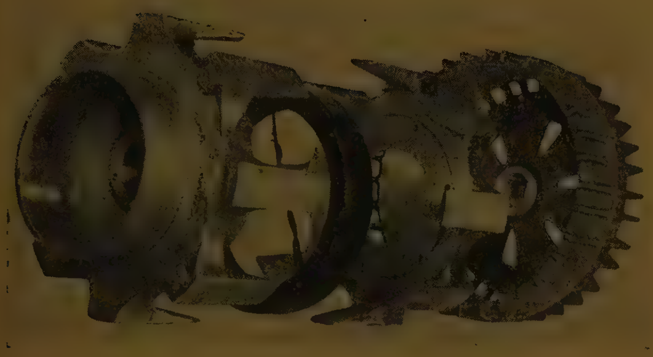


Figure 7 (below). **Field member components of the overlap tooth clutch**

EXCITATION AND CONTROL REQUIREMENTS

The energy required for field excitation of both the slip coupling and the dynamometer is relatively small and not in proportion to the rating of the machines. For example, a 5-horsepower 1,800-rpm unit requires about 100 watts of field excitation, while a 100-horsepower 1,800-rpm unit requires about 200 watts of excitation.

The use of an electronic control for close speed regulation is an ideal application. The field then is supplied by current rectified by means of the thyratron tube. The speed of any size machine then can be controlled by the positioning of a 50-watt potentiometer rheostat. The potentiometer varies a reference voltage in combination with a small governor generator which supplies only a fraction of a watt. The speed can then be controlled within one per cent over a load change of 10 to 100 per cent on production electronic controls. Special applications, however, have held the speed regulation to within 0.1 per cent.

METHODS OF COOLING

For dynamometers an original type of water cooling is illustrated in Figure 11 where parallel cooling channels are machined around the circumference (water flows from top to bottom). Under heavy loads the temperature differential between the air gap side and the cooling water surface is very high, especially if boiler-scale forms an insulating surface.

An improved method of dynamometer cooling was obtained by running the cooling water in the end-bell of the unit so that the water passes between the teeth of the rotor and comes in contact with the armature surface where the eddy currents are generated. The water drain then is large enough to prevent a head of water forming within the machine, although a suction pump may be employed. The hydraulic drag on the toothed rotor may account for 25 per cent of full load torque; the hydraulic loading on the smooth rotor amounts to only 2–5 per cent.

Water cooling usually is preferred for slip couplings though air cooling is used on low-loss units. The usual practice in water-cooling couplings is to spray the water on the outside surface of the armature.

APPLICATIONS

Because the clutch can be controlled with such low power, and speed can be set in an infinite number of increments, the eddy current clutch when used in con-

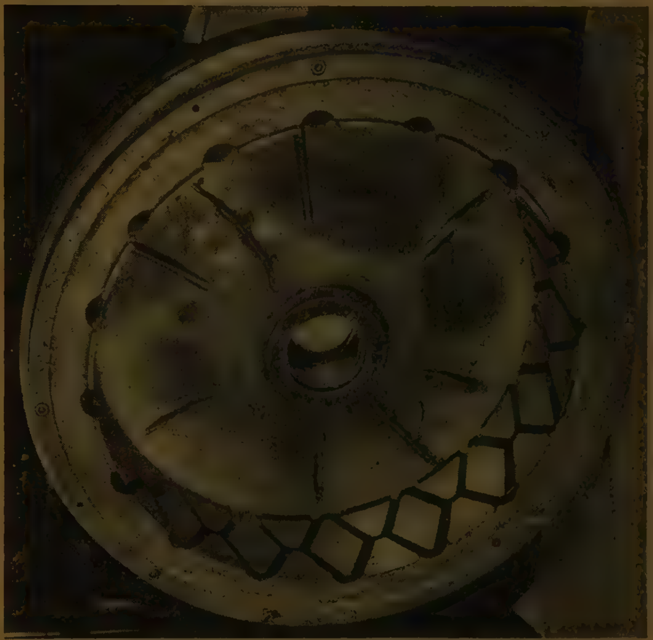
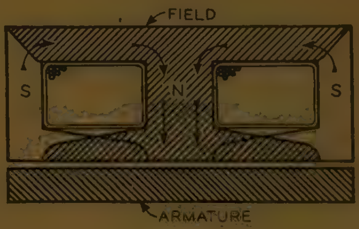


Figure 8. **Multiple field section**

The center member acts as a common flux carrier for the two independent excitation coils

Figure 9. **Cross section of multiple field shown in Figure 8**



junction with an electric motor forms an ideal combination for variable speed drives.

The motoring and absorbing (dynamometer) unit is shown in Figure 12. The output shaft is driven by the clutch armature. The induction motor drives the field member (inner member). When coupled to an engine, the induction motor serves to crank the engine, or drive it at a governed speed, and to record friction loss by measuring torque with a cradle-type mounting. A stator field member is built outside of and around the armature, thus enabling the clutch to act as a dynamometer when the outer field is energized. A manual switch is used to select the field to be energized.

Slip couplings are well adapted for ship propulsion where the cushioning of engine vibration and power pulses contribute to smoother riding by preventing these vibrations from entering the propeller shaft. Another application is the simulation of flight condition in the production testing of aircraft engines.

Heavy duty steel mill applications requiring reversing cycles can be met by using two eddy current clutches rotating in opposite directions, each driven by a synchronous motor. The direction of rotation of the machine is determined by controlling clutch energization.

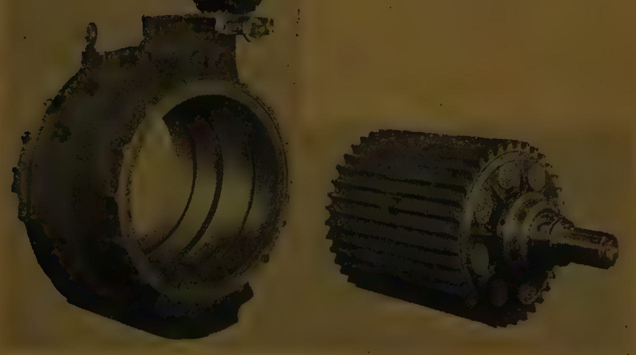


Figure 10. Dynamometer rotor and stator

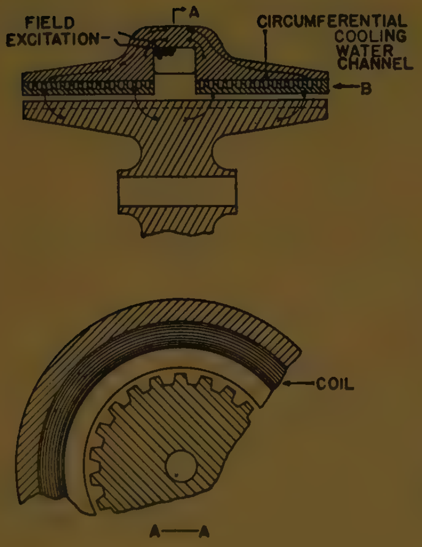


Figure 11. Dynamometer cross section view of field, armature, and flux path

Dynamometers of this type range in size from 30 to 3,000 horsepower at 3,500 rpm

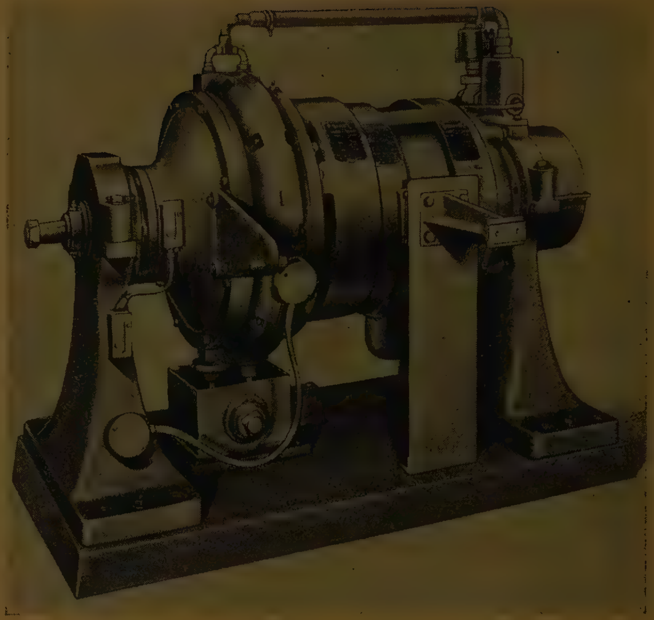


Figure 12. Motoring and absorbing combination dynamometer

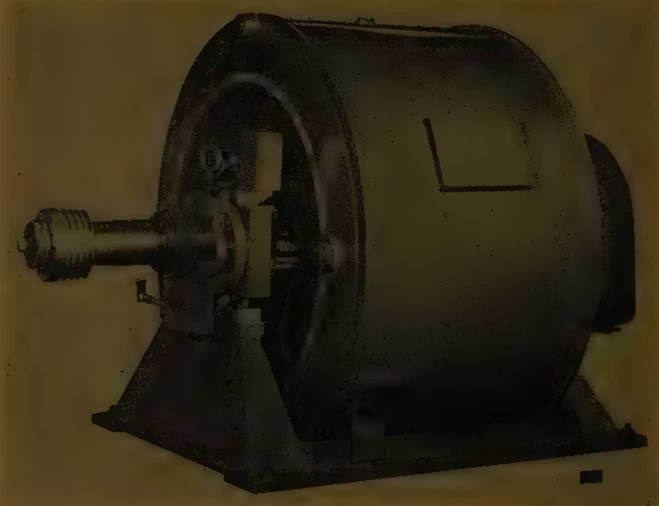


Figure 13. A 2,000-horsepower coupling used for aircraft testing

The automotive field is beginning to adopt the eddy current slip clutch for heater fan, generator, and fan drive variable-speed control. Commercial automotive engine truck tractors for plant use are finding this the answer to their clutch maintenance problems. The eddy current brake has many applications. Such brakes are similar to the dynamometer except that the stator is not cradled.

The largest brakes are used in oil well drilling. Eddy current clutch and brake combinations have found recent application in the operation of punch presses. The heaviest highway trucks easily can descend the steepest grade without the dangers of overheating eddy current brakes.

Test of Silicones for Shipboard Use

H. P. WALKER

Naval electric power equipment, as well as commercial machines, may be reduced in size and weight by the development of new silicone insulating materials. Tests are still in progress which indicate that fire and arc resisting products will be obtained that can also meet other Navy specifications.

THE ever-present problem of smaller lighter weight more reliable electric equipment for ships has prompted the Bureau of Ships, United States Navy Department, to inaugurate a test program to determine the possible uses of silicones as insulating varnishes, resins for building laminated and molded thermosetting materials, resins for high temperature paints, lubricants for bearings, and rubber for gaskets.

At present the bottleneck in reduction of size or weight of many types of electric equipment, such as motors, generators, and transformers, is the 125-degree-centigrade temperature limit for class *B* insulation. Assisted by leading manufacturers of motors, silicones, transformers, glass, and laminates, the Bureau of Ships formulated a testing program consisting of four parts

1. Laboratory tests on basic materials.
2. Simulated service tests on special motors.
3. Simulated service tests on electric equipment designed "from the iron up" to take full advantage of the heat endurance of silicone products.
4. Installation of silicone equipment designed for actual shipboard operation.

SILICONE VARNISH

Laboratory tests on three silicone varnishes, *DC-990A*, *DC-993*, and *DC-996*, consist of flexibility tests after heat aging, cold checking, dielectric strength (both dry and wet), insulation resistance, abrasion, and so forth. Flexibility tests made on varnish films baked on aluminum panels indicate that the best life is obtained at 1,750 hours at 225 degrees centigrade (before the film cracks when bent over a 1/8-inch mandrel). When compared with similar tests on organic varnishes, this gives silicone varnishes a margin of about 100 degrees centigrade.

Results of life tests on standard motors using glass-covered wire, glass and mica tape, and *DC-990A* varnish were so extraordinary that an extensive program of special motor testing was undertaken. Ten-horsepower 440-volt 3-phase 60-cycle motors were wound with glass-covered wire, glass and mica tape, and *DC-993* impregnated varnish. Special precautions were taken to keep the bearing temperatures below 100 degrees centigrade so that the heat stability of the insulation could be tested without running into bearing trouble. A test procedure was set up to approximate actual shipboard operation. The motors were run at high temperatures followed by humidification. In such a cycle the heat run produces actual aging or deterioration of the insulation and the humidification serves as an indicator of weakness that may have developed from the heat. It was attempted to time the cycles so that there would be 25 during the life of the insulation. (Insulation life was estimated from the flexibility tests.) Only actual running time of the motor was considered. The test was started several years ago and is still in progress. Data as of August 1, 1946, are reported in Table I. From all the data available to date, it is considered that a total hot spot temperature of 200 degrees centigrade maximum may be a satisfactory tentative limit for Navy rotating equipment utilizing this type of silicone resin, provided the bearing problem can be solved.

Similar thermal aging tests on *DC-996* motors now are being started. A d-c *DC-990A* subway traction motor was operated 1,675 hours at 285 degrees centigrade (hot spot temperature of 300 degrees) without failure before tests were discontinued and the motor replaced with a *DC-993* traction motor. Tests are now starting on this motor. Another set of tests made on a group of motor controller contactor coils of the solenoid type revealed that when the coils were operated at 275 degrees centigrade, the resistance of the coils increased from about 1.5 per cent at 7,000 hours to eight per cent at 12,000

Table I. Silicone-Insulated-Motor Tests

Material	Temperature, C	Cycles	Hours	Years at 160 C*	Remarks
DC-993	310	46	5,131	3,395	Failed on 47th cycle
DC-993	300	44	5,402	2,040	Still running
DC-993	280	35	6,600	773	Still running
DC-993	240	1	189	2	Recently started
DC-993	240	1	221	2	Recently started
Class *B* and *DC-996*	275	35	1,280	111	Original class *A*
Class *B*	275	33	1,056	92	Failed on 33d cycle
Class *B*	200	40	3,760	4	Failed on 40th cycle

* Extrapolated on basis of 10-degree rise in operating temperature reducing life by 1/2.

Essential substance of paper 47-132, "Silicone Insulation as Applied to Naval Power Equipment," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947, and scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

H. P. Walker is an electrical engineer in the electrical department of the Bureau of Ships, United States Navy Department, Washington, D. C.

Table II. Properties of Laminated Glass-Silicone Insulating Material

	Navy Desires	Manufacturers' Data
Mechanical properties		
Flexural strength, condition *A**, 1/2-in., psi		
Flatwise, lengthwise	22,000	18,000
Crosswise	17,000	20,000
Edgewise, lengthwise	22,000	16,500
Crosswise	17,000	16,700
Tensile strength, condition *A**, psi		
Lengthwise	18,000	17,700
Crosswise	12,000	7,730
Compressive strength, condition *A**, psi		
Flatwise	30,000	38,000
Edgewise, lengthwise	10,000	11,900
Crosswise	10,000	10,200
Izod impact strength, condition *A**, ft-lb per in. of notch		
Flatwise, lengthwise	16	17.0
Crosswise	16	11.6
Edgewise, lengthwise	16	7.0
Crosswise	16	4.8
Bonding stength, condition *A**, lb		
Lengthwise	1,200	860
Crosswise	1,200	860
Water absorption, condition *D** 24 hr at 25 C, per cent 1/8 in. thick	0.50	0.40
Electrical properties		
Dielectric strength, condition *A**		
Perpendicular, step by step, v per mil	275	295
Short time, v per mil	275	315
Parallel, step by step, kv	50	41
Short time, kv	50	69
Dielectric losses		
1 megacycle, condition *A**		
Power factor, per cent	0.10	0.14
Dielectric constant	3.50	4.25
Loss factor, per cent	0.40	0.60
1 megacycle, condition *D** 24 hr at 25 C		
Power factor, per cent	1.00	0.81
Dielectric constant	4.00	4.57
Loss factor, per cent	4.50	3.90
30 megacycles, condition *A**		
Power factor, per cent	2.00	0.25
Dielectric constant	4.00	4.19
Loss factor, per cent	8.00	1.05
30 megacycles, condition *D** 24 hr at 24 C		
Power factor, per cent	4.00	0.80
Dielectric constant	4.00	4.29
Loss factor, per cent	16.00	3.43
Insulation resistance, megohms		
Condition *A**	125,000	200,000
Condition *D** 96 hr at 50 C	1	264
Condition *D** 96 hr at 30 C and 96 per cent relative humidity	1,000	
Arc resistance, condition *A**, sec	300	265

* For complete specifications see *JAN P-13*, Plastic Materials Laminated Thermosetting Sheets and Plates. United States Government Printing Office, Washington, D. C., September 1944.

hours. This indicates that at temperatures of 275–300 degrees centigrade the copper wire oxidizes, thereby reducing its diameter and increasing its resistance. This oxidization can be discouraged by plating the wire with cadmium.

Lighter and more compact dry-type power distribution transformers rated at 440/117 volts, single-phase, 3 kva and 25 kva at 150 degrees centigrade temperature rise have been built and tested. The coils are insulated with glass-served silicone-bonded wire (*DC-993*) and impregnated with silicone varnish. Silicone-varnished glass cloth is used as layer insulation. Silicone glass laminated insulation is used for coil bracing. Because of the high operating temperature, lead wire is insulated with silicone rubber. The enclosing case is painted with silicone paint. The electrical characteristics of these transformers indicate that the regulation at 100 per cent power factor for the 3-kva unit is 2.93 per cent and for the 25-kva unit, 2.19 per cent At 80 per cent power factor, the regulation for the 3-kva unit was 3.68 per cent and for the 25-kva unit, 2.10 per cent. The temperature rise data indicated that temperatures of 106 degrees centigrade and 110 degrees centigrade were obtained in the voltage coils. In order to fully utilize the 150 degrees centigrade temperature limit, further studies are being made to determine how the regulation values and losses can be adjusted without affecting the over-all performance of the electric power system.

LAMINATED INSULATION

Detailed investigations of glass, cloth, and silicone resin combinations are being conducted to determine

1. What sizing, if any, should be used on glass cloth.
2. Continuous versus staple fiber glass filaments.
3. Type of weave to give maximum properties.
4. Woven versus nonwoven glass materials.
5. Thermosetting properties of silicone resin.
6. Improvements of silicone resin for mechanical strength.

The desired properties of a fire and arc resistant laminated material are shown in Table II as compared with the best obtainable properties from a study of various manufacturers' test data. Preliminary applications of this material have been made in various types of naval electric equipment with excellent results, especially where heat resistance is of prime importance.

Not all of the desired properties have been obtained as yet, nor have all the properties been available in a single combination of glass and resin, but encouraging results have been achieved. The development work has indicated that

1. Starch and oil sizings on the glass cloth are deleterious and must be removed before any resin treatment is made.
2. Heat cleaning has a tendency to weaken the glass.
3. Chemical cleaning reduces the tensile strength of the glass.
4. Water soluble sizings are satisfactory.
5. Silicone oils as sizings adversely affect the mechanical properties.
6. Silicone "elastomers" are satisfactory as sizings.
7. Silicone resin should have high solids content.
8. After-baking treatment of laminate should start at relatively low temperature to prevent blistering.

MOLDED INSULATION

The development of a fire and arc resistant molded silicone-glass material likewise is being accompanied by a detailed investigation.

1. What sizing, if any, should be used on glass filaments.
2. What length and diameter glass gives optimum mechanical strength.
3. What catalyst concentrations should be used.

4. Effect of addition of inert fillers on properties.
5. Use of present available molds.
6. Hot ejection from the molds.
7. After-baking cycle to prevent blistering.
8. General moldability and wear.

As can be seen from the data in Table III, there is still development work to be done before producing a moldable material having the desired characteristics. The following considerations must be taken into account in producing a high impact grade of material:

1. Unsized or silicone-sized (*DC-2103*) glass should be used.
2. Fiber length should be between 3/4 and $1^1/_2$ inches.
3. Resin should have high solids content.
4. Mixing machinery should be of a type which will not tear the glass fibers.
5. Milled glass fibers are not satisfactory. Random chopped fibers are satisfactory.
6. Molding compound should be heated to drive off volatiles before molding.
7. After-bake should be at relatively low temperature to prevent blistering of part.

Table III. Properties of Molded Glass-Silicone Insulating Material

	Navy Desires	Manufacturers' Data
Mechanical properties		
Izod impact		
Ft.-lb.	1.20	0.81
Ft-lb per in. of notch	2.40	1.62
Ft-lb per in. sq	15.00	10.12
Flexural strength, psi	9,000	6,515
Tensile strength, psi	5,000	2,666
Compressive strength, psi	20,000	10,588
Shrinkage, mils per in.	8.0	1.39
Specific gravity	1.60–1.70	1.70
Water absorption, 47 hr, per cent	1.5	0.60
Ash, per cent	85.00	86.00
Heat distortion, mils at C	5.0/250–300	3.0/-300
Electrical properties		
Dielectric strength, step by step, 100 C	150	156
Dielectric losses, 25 C		
1 megacycle dry		
Power factor, per cent		0.14
72 hr wet		
Power factor, per cent	0.10	9.92
Dielectric constant	3.5	4.56
Loss factor, per cent	0.40	45.12
Volume resistivity, megohms per cm cube	20×10^5	8.78×10^5
Arc resistance, sec	300	263

FUTURE DEVELOPMENTS

Several general problems still exist in the development of silicone insulating materials.

1. Toxic effects of products of decomposition, if any, of silicone materials used for motor insulation.
2. Cause and correction of commutating difficulties and excessive brush wear on silicone-insulated d-c motors and generators of the enclosed type using air recirculation.
3. Development of a satisfactory silicone enamel for magnet wire which will not crack or peel and which will not be soluble in impregnating varnish.
4. Variation in arc resistance of molded and laminated material and variation in test methods.
5. Improvement in fire resistant characteristics.

It is believed that many of the problems which are solved under this program will aid commercial utilization of better insulating materials, and the resulting widespread usage and volume production will help to reduce the present high cost of silicone and glass products.

Radiation Detector

Radiations from exploding atoms are counted at the rate of 100,000 each second by a radiation detector developed by the Westinghouse Research Laboratories. The new detector is said to be 50 times more effective than the standard Geiger counter whose limit is about 2,000 radiations per second.

Shown here is a small piece of wire tipped with radioactive material being held a few inches away from the detector which is enclosed in the light-tight box in the foreground. The rays penetrate the box and enter the detector where they strike a fluorescent screen producing light which is converted to electricity and amplified a million times by a photomultiplier tube. This signal is sent to the oscilloscope where the exploding atoms appear as flashing peaks of light, or it can be transmitted to suitable electronic circuits which record the number of particles being radiated.

Cable Carrier Developments

The K2 telephone cable carrier system is providing dependable long distance communication with improved performance at reduced cost, saving in raw materials. The portable testing equipment developed for use on the K2 system also can be used to test the K1 system and certain open wire channels.

CABLE CARRIER SYSTEMS have been used for telephone communications for more than eight years. The *K1* system developed by the Bell Telephone Laboratories provided means for transmitting 12 1-way messages simultaneously over a single 19-gauge cable pair. Two cable pairs are necessary for 2-way communications. Some 2,500,000 miles of *K1* carrier cable are in use for long distance message circuits. Another 2,500,000 2-way message circuit miles of carrier cable have been installed during the past three years using the recently developed more economical *K2* system.

The *K2* system is designed to provide 12 satisfactory message circuits with an over-all signal which will remain constant within very close limits for distances over 4,000 miles with the necessary 240 or so tandem amplifiers and cable sections. This necessitates compensation for the aggregate attenuation of the wires themselves, the variation of loss with frequency, and the continuous variation of transmission characteristics with cable temperature. Regulation is accomplished automatically with a minimum of apparatus and no moving parts by using thermistors to vary the gain of feed-back amplifiers. Because each amplifier is regulated individually, the errors in output of the many amplifiers comprising a long system are not accumulative.

The 12 telephone message channels are 4 kc apart beginning at 12 kc. Upper side-band modulation is used. As the voice frequency span extends from 100 or 200 cycles to less than 4,000 cycles, space is left for "pilots" whose frequencies coincide with suppressed carriers and are 12, 28, and 56 kc. These pilots along with a fourth pilot at 60 kc (outside the range of frequencies occupied by the channel side bands) can be used to control the regulators.

AMPLIFIERS

Matching the various cable losses with gain to a high precision is accomplished with three kinds of amplifiers, transmitting, line, and twist. The three kinds of amplifiers are designed to complement each other in the over-all compensation for the ever-changing cable losses. They are all of the negative feed-back type. Line amplifiers are by far the most numerous in the system; normally they are spaced about 17 miles apart, although spans may vary from 11 to 20 miles. Line amplifiers have three important functions; they provide the necessary high gain to make up for the loss of the preceding cable span; at an average temperature of the cable, they equalize for the variation of this loss between 12 and 60 kilocycles; and they regulate the gain automatically. Thereby they compensate for the major portion of the variation in transmission with temperature; namely, that portion which is independent of frequency and termed "flat gain". Figure 1 is a schematic diagram of the line amplifier. Although the thermistor in the feedback path has considerable thermal lag, it is sensitive enough to respond to even the weak currents in the feedback path and control the output gain of the amplifier by controlling the amount of feedback. Thus, the rms value of the output current is held constant despite variations at the input, and changes in cable loss are compensated automatically without the use of moving parts. To make such a scheme work, the power which reaches the line amplifier must be constant except of changes resulting from variations of the loss in the preceding span. To accomplish this a transmitting amplifier is inserted at the sending end of the cable and oscillates continuously at 60 kc. The 60-kc power output is regulated to supplement the sum of the various signal outputs to maintain constant rms power output.

This unusual operation of the transmitting amplifier is due to the simultaneous action of two feedbacks—one negative and one positive. The negative feed-back path is quite orthodox, and sets the amplifier gain at its required value. The positive path includes a thermistor—in this case a low wattage resistance lamp—and an oscillator coil. Like other hermistor-controlled oscillators, the oscillations increase in magnitude and heat the thermistor until its resistance is just the right value to make

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Based upon two papers: 47-109, "An Improved Cable Carrier System," by H. S. Black (F '41), F. A. Brooks (A '36), A. J. Wier (A '36), and I. G. Wilson, and 47-111, "New Test Equipment and Testing Methods for Cable Carrier Systems," by W. H. Tidd (A '31), S. Rosen, and H. A. Wenk. Both papers were presented at the AIEE North Eastern District meeting, Worcester, Mass., April 23–25, 1947, and are scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

H. S. Black is high frequency transmission engineer in the transmission development department of Bell Telephone Laboratories, Inc., New York, N. Y.; **F. A. Brooks, A. J. Wier,** and **I. G. Wilson** are members of the technical staff of Bell Telephone Laboratories; **W. H. Tidd** is in the transmission development department of Bell Telephone Laboratories; **S. Rosen** and **H. A. Wenk** are also with Bell Telephone Laboratories.

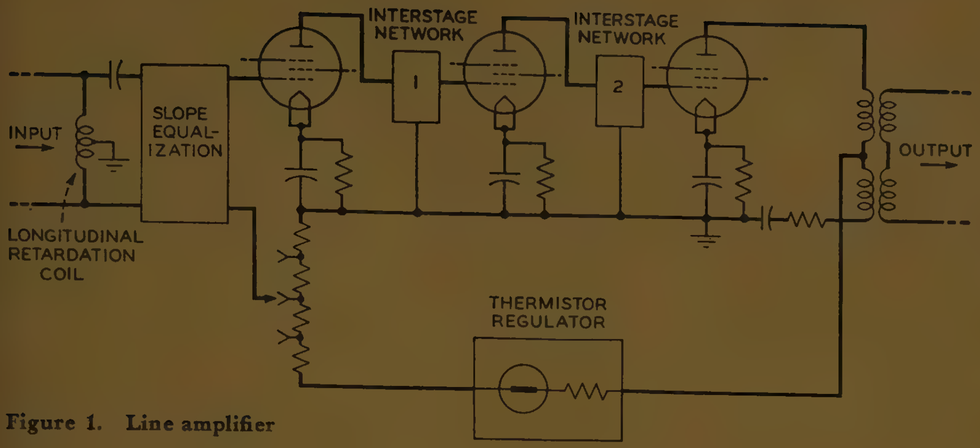

Figure 1. Line amplifier

the loss of the positive feed-back path equal to the gain of the amplifier. Although the tuned oscillator coil and positive feedback limit the voltages fed back over this path to a narrow band of frequencies centered around 60 kc, the thermistor portion of this path is made equally responsive to all significant frequencies. Consequently, signal currents when present also flow through the thermistor and heat it. Because the resistance of the thermistor cannot be changed if the loss of the positive feed-back path is to equal the gain of the amplifier, the oscillations, therefore, grow weaker until the rms or heating value of the signal currents plus oscillations becomes the same as that of the oscillations alone in the absence of signals. This automatically provides a nicety of control and insures constant rms output from the transmitting amplifier. The lamp has low thermal lag so that it substantially follows the signal variations.

Of the three types of amplifiers, the twist is the most complex. It not only does everything a line amplifier does but also compensates for variations in cable loss which are functions of frequency. Twist amplifiers are used only when these variations, which are small compared with the total, accumulate and necessitate their insertion. They are inserted at every fifth or sixth station on aerial cables and at longer intervals, not exceeding 15 stations, on underground cables. To control the gain of the twist amplifier, three weak sinusoidal waves having frequencies of 12, 28, and 56 kc are continuously transmitted to the line at constant magnitude. These pilots appear at the output of the twist amplifier, and are selected by narrow band crystal filters and separately amplified. By suitable control circuits which change variable networks in the feed-back path, the gain of the amplifier at 12, 28, and 56 kc is set so that the output of each pilot is maintained constant. The 56-kc pilot controls a fast-acting flat gain regulator whose control element is a thermistor. The two variable equalizers controlled by the 12- and 28-kc pilots also use thermistors as variable resistance elements.

The forward acting portion of each of the three amplifiers uses the same tubes and substantially the same parts. Although similar in many respects, the feed-back portions differ significantly because the function of each is markedly different. In each case, the maximum amplification without feedback is 115 decibels and the amount of negative feedback varies from about 40 to more than 60 decibels. The feedback is large because of the extreme linearity required to use a common amplifier for 12 channels, and the fact that both the automatic and fixed gain adjustments are made by varying the loss of the feed-back path, low figure of merit* vacuum tubes which have reasonably long life and minimum filament and plate power requirements are used, thereby tending to conflict with the high feedback requirements. Nyquist's principle of conditional stability (looped over amplifiers) was used as a practical means of solving this problem.

The good impedance match required between amplifier and cable is obtained by a simple hybrid coil feedback connection at the output and by series feedback at the input. The low-side output impedance is controlled mainly by the impedance of the balancing network of the hybrid coil and is stabilized by the negative feed-back action of the amplifier. At the input, the feedback reduces a substantial portion of the grid and transformer

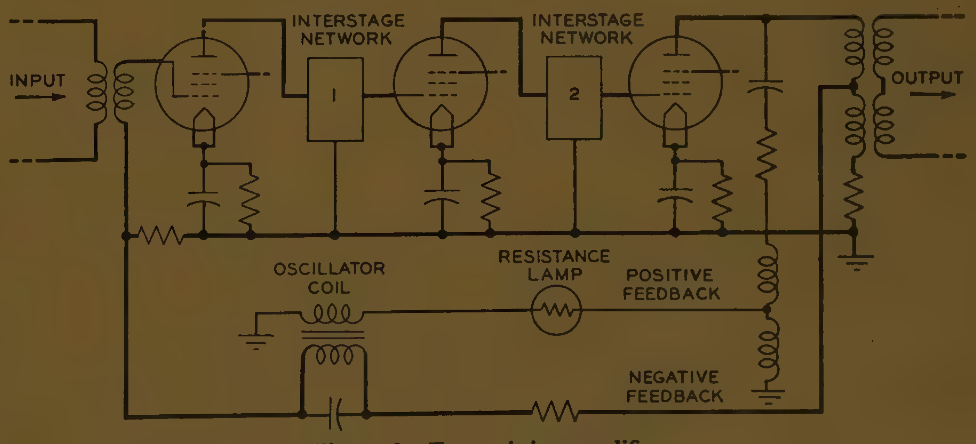

Figure 2. Transmitting amplifier

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* A discussion of figure of merit may be found in engineering handbooks. Radio Engineers' Handbook, F. E. Lerman. McGraw-Hill Book Company, New York, N. Y., 1943. Page 433.

capacitances so that greater step-up ratios can be used to override inherent tube noise and still obtain a satisfactory termination for the input equalizers.

EQUALIZERS

Each line or twist amplifier provides basic equalization to compensate for the average characteristic at a predetermined temperature of the preceding section of cable. Provision is made for spans of various lengths by supplying additional characteristic slopes. These characteristics are obtained essentially from the combination of the input transformer and equalizer. Slopes equivalent to 13, 15, and 17.5 miles of cable are obtained by restrapping certain elements, a change which can be made readily during installation or subsequent line-up. For the occasional 20-mile span, basic equalization is obtained by the use of an auxiliary equalizer to supplement the slope afforded by the 17.5-mile strapping.

Because the basic equalizers have so few parts, the over-all gain of the line and twist amplifiers does not match the cable loss precisely. The differences are small and intentionally given shapes which can be equalized readily and economically by a special deviation equalizer inserted at intervals of five to eight repeater spans.

Figure 1 illustrates how an equalizer structure which is left unbalanced to save elements is enabled to meet the high balance requirements for toll cables by bridging a longitudinal retardation coil across the incoming pair and grounding the mid-point.

REGULATORS

Each regulator measures its control signal and then makes an appropriate correction in the gain of the amplifier, thus falling in the classification of "backward acting regulator." It is well known that if the precision of control of such regulators is too exact, the system may hunt. The steady-state envelope response of the loop path is used to apply Nyquist's criteria for stability or to evaluate its transient behavior in the design to the *K2* regulators.

In the *K2* system, there are the additional problems of the effects upon stability of many regulators in tandem and of the continuous simultaneous control of the twist amplifiers by three different regulators. To minimize the latter problem it is necessary to select the pilot frequencies and network shapes so that interactions are small. To reduce the effect of the fast-acting 56-kc flat-gain-control regulator on the slope and bulge thermistors they are made slow acting. Their thermal lag is so great that they are affected to only a negligible extent by the rapid corrections of the flat gain regulator.

TRANSMISSION PERFORMANCE

Over even the longest circuits, the basic equalization compensates for the cable loss to within a few decibels and the terminals provide facilities for adjusting the transmission over individual channels to the value sought. The regulators maintain this transmission as the temperature of the cable changes to within about plus or minus one or two decibels. With the good transmission stability which these systems provide, they are used to carry the usual services encountered in the toll plant such as signaling, telephone messages, and multichannel voice frequency telegraph and high quality program channels.

EQUIPMENT

In the larger centers, the equipment is installed in existing telephone buildings where systems may terminate. Approximately two thirds of the installations are in new unattended single-story brick buildings in which heating and ventilating are controlled automatically.

Cross talk between office wiring at like transmission levels is kept sufficiently low by using high grade low impedance (135-ohm) rubber-covered shielded pairs about 3/8 inch in diameter. These hang loosely in the bay cable duct and are laid on cable racks without sewing. Wiring carrying high output power is separated from input wiring by segregating the outputs and inputs on the right and left sides, respectively, of the mounting bays. A cable duct type bay permits doing this in an efficient manner.

One of the difficult problems is to guarantee low cross talk between adjacent amplifier panels. For this purpose, and to keep unwanted couplings within the amplifier to a sufficiently low value, direct wiring is used and all panels are flanged to overlap the can covers. On the line amplifier nonmagnetic material for the panel and cover further helps to provide adequate shielding.

Uninterrupted service and infrequent maintenance necessitate continuous and dependable power supply sources. In main stations regular 24- and 130-volt storage batteries are used in series for the plate supply.

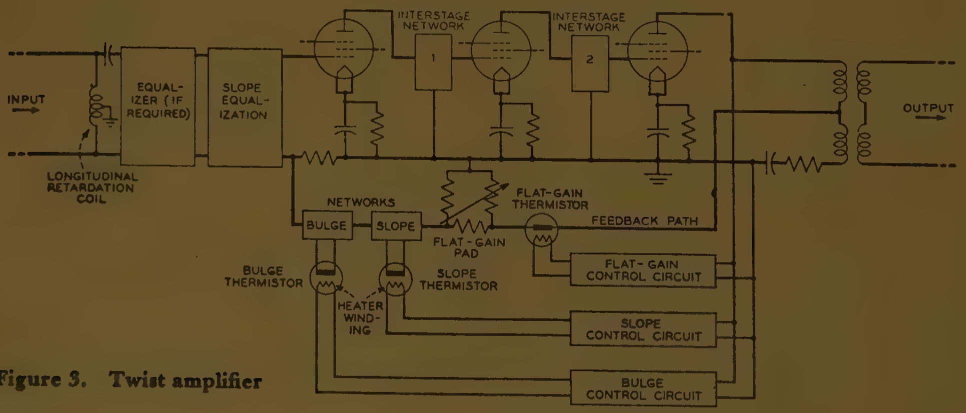

Figure 3. Twist amplifier

In auxiliary stations, a 152-volt battery is provided. The filaments are heated by regulated 60-volt 60-cycle alternating current fed to filament transformers located on each amplifier. In case of power failure, emergency power is obtained from the battery by means of an inverted converter. The converter starts automatically upon failure of outside power and before the filaments cool enough to affect appreciably the transmission performance of the feed-back amplifiers. During a protracted power failure, a portable engine-driven generator is caused to charge the battery at an auxiliary station.

TEST EQUIPMENT

A complete new line of portable test equipment was developed for use on the *K2* carrier system, comprising a sensitive highly selective transmission measuring set, a decade oscillator, and a tube test set. The first two of these also can be used on 3- and 12-channel open-wire systems and the *K1* cable system. The portable sets are much smaller and cheaper than previous equipment and fewer sets are needed.

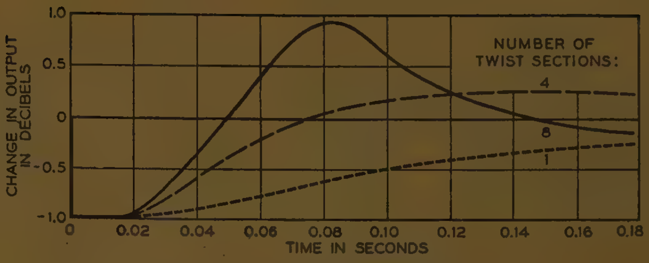

Figure 4. Decibel response of 56-kc regulators to a sudden increase in input loss of one decibel

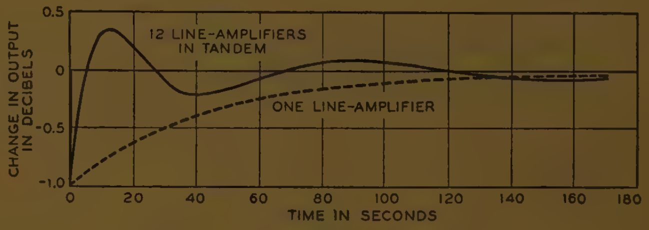

Figure 5. Decibel response of line amplifier regulators to a sudden increase in input loss of one decibel

Transmission Measuring Set. A simplified diagram of the *31*-type transmission measuring set is shown in Figure 6. The set has an input impedance of 8,000 ohms which permits bridging measurements on the system in operation without affecting service. A high sensitivity of from 95 decibels below one milliwatt to 35 decibels above one milliwatt permits measurements at both the input and output of the amplifiers. Extreme selectivity is necessary to enable the measurements of pilot frequencies and other test signals on the working system with adjacent communication channels busy. The nominal bandwidth of the set is 50 cycles and the selectivity at 400 cycles away from midband is at least 32 decibels and continues to increase with distance from midband. Over the frequency band the sensitivity is uniform to within plus or minus 0.5 decibel. The set is operated at 115 volts alternating current and requires about 70 watts. The set is divided into two portions, the selector and the detector. An input switch makes it possible to connect the input cord either to the detector or the two portions in tandem. Other positions of the switch connect equipment for special purposes; a 49-kc crystal filter can be inserted ahead of the selector to provide preselection for certain tests; a 40-decibel voltage divider can be connected ahead of the selector for calibration. When the input switch is in the selector position, the input transformer which has a 1:1 ratio is terminated in a fixed step voltage divider having a total impedance of 8,000 ohms. This is the selector sensitivity control and is arranged in 10-decibel steps. A wide band stage precedes the modulator or first converter of the set which is a double-balanced modulator using a bridge arrangement of copper-oxide varistors. The primary purpose of this is to obtain some local oscillator balance. The modulator is followed by a crystal filter at 455 kc. This filter is required to obtain the extreme selectivity which is needed for system measurements. A 2-stage intermediate frequency amplifier with double-tuned interstages follows the crystal filter.

The heterodyne type of set was selected so that the selectivity could be obtained at any point in the frequency band. The choice of 455 kc for the intermediate frequency was based on a study of spurious responses possible. Performance in this respect is considerably better than that for a system in which the intermediate frequency is located either below or just above the band of the set.

The oscillator for the converter or modulator is a simple coil feed-back type of oscillator with the frequency determining circuit in the screen grid circuit. The oscillator frequency range is 465–605 kc. The output is coupled by means of the electron stream to the plate circuit and is supplied to the modulator by means of a transformer.

The detector portion of the set is a 3-stage amplifier with negative feedback. The output of this is connected to a half-wave diode rectifier. The negative feedback is sufficient to give the amplifier long time stability and also to improve the linear response of the output meter and rectifier circuit. The linear half-wave rectifier, or so-called averaging detector, was selected because of its superiority for measuring a signal in the presence of unwanted signals. An unwanted signal 13 decibels below the signal to be measured causes an error of only 0.1 decibel.

The detector portion of the set may be used separately for measuring signals over the frequency band from 1 to 150 kc where selectivity is not required. The sensitivity is from 25 decibels below one milliwatt to 35 decibels

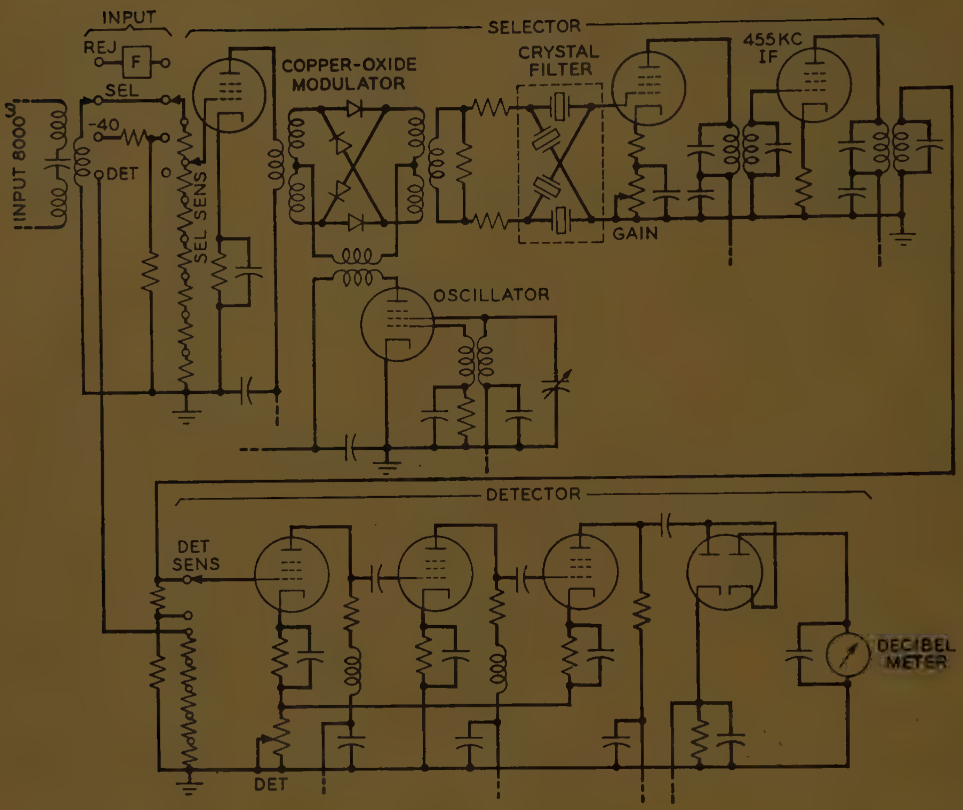

Figure 6. Simplified circuit of the 31A and B transmission measuring sets

above one milliwatt. The stability with time of this section is 0.1 decibel.

A high impedance test probe has been designed as an accessory for the *31*-type set for making measurements of voltages within an amplifier of the system. The impedance is approximately 800,000 ohms and the effective shunt capacitance about nine micromicrofarads. The probe is essentially a 40-decibel pad which plugs into the input transformer in place of the normal input cord. The voltage divider consists of an 800,000-ohm resistance which in series with the 8,000-ohm input impedance of the set causes a 40-decibel loss. A small adjustable capacitance is connected across the 800,000-ohm resistor in order to equalize the transmission characteristic over the frequency band, to compensate for the capacitance of the cord.

PORTABLE OSCILLATOR

The *51A* oscillator consists essentially of a Wien bridge circuit for frequency determination, a 2-stage amplifier, and a cathode follower stage to provide a low impedance output (135 ohms). A simplified circuit is shown in Figure 7.

In this oscillator, the capacitances of the series and parallel frequency determining arms have been made constant, hence the frequency is proportional to the conductance. This makes possible the decade method of frequency selection. There are two decade switches, one of which connects resistances in the series and shunt frequency determining arms of the bridge circuit for the 10-kc steps, the other connecting resistances for the 1-kc steps. The addition of any positions of these two switches makes it possible to set frequencies in steps of 1-kc. A pair of variable resistances also connected in parallel with the decade switches permits continuous variation of frequency between the 1-kc frequency steps. It is, of course, possible to extend the decade system to smaller steps if desired. Resistors of 0.1 per cent accuracy are used in the frequency determining network. Trimming of the residual conductance inaccuracy and the stray circuit capacitances is accomplished with small variable condensers connected in each step of the shunt bridge arm.

In this type of oscillator, an adjustable resistor is usually provided in place of the thermistor in one of the resistance arms of the bridge and adjusted to slightly more than twice the operating lamp resistance so that a balance is reached between the positive lamp characteristic and the reduced voltage supplied to the amplifier grid in case of frequency or supply voltage fluctuations. It was found that a thermistor with a negative slope resistance characteristic when substituted for the adjustable resistor, automatically would compensate for the lamp characteristic. Since the amplitude of oscillation is controlled by the thermistor and lamp arms of the bridge, the tubes are permitted to operate over substantially linear portions of their characteristics. Also, the lamp and thermistor, being thermal devices, respond to changes in the effective value of applied voltage and not the instantaneous. This results in an output signal of good wave shape.

The frequency accuracy of the oscillator for any setting of the frequency switches is approximately 0.1 per cent. The oscillator is factory-adjusted by means of the potentiometer designated *CAL*, to deliver a maximum of 16 decibels above one milliwatt into a 135-ohm load. The *COARSE* and *FINE* controls enable the output to be reduced to less than 75 decibels below one milliwatt. The oscillator output impedance is substantially 135 ohms throughout the frequency range and is independent of the setting of the output controls. The total power of any spurious frequencies including harmonics and power supply interference is at least 30 decibels below the fundamental and is substantially independent of the amplitude or frequency of the fundamental output signal. A plus or minus 5-volt variation of the a-c power supply voltage produces less than 0.1 decibel variation of the oscillator output. The frequency stability for a-c power supply voltage variations is of the order of 20 parts per million per volt.

The simplicity of operation and stability of output make this oscillator convenient for field testing and maintenance.

Tube Test Set. The *1AH* tube test set was specifically designed for testing the *373A* and *374A* filamentary type pentode vacuum tubes used respectively as voltage amplifier tubes and power output tubes in the amplifiers. Since these tubes were a new development and were being applied to a new system, the opportunity was presented to develop new testing criteria and testing techniques which not only would determine the present condition of the tubes but also provide some better indication than had been available previously as to whether satisfactory performance would be obtained for at least the period of future operation until tests were again made. With this in mind the tube test set was designed to measure the following tube characteristics:

1. Dynamic transconductance or G_M.
2. Peak plate current when the grid is driven to zero bias.
3. D-c plate current.
4. Filament activity which is indicated by the change in the characteristics when measured with the filament voltage reduced by ten per cent.
5. Grid current.
6. Maximum power output of the *374A* tube under amplifier load conditions.

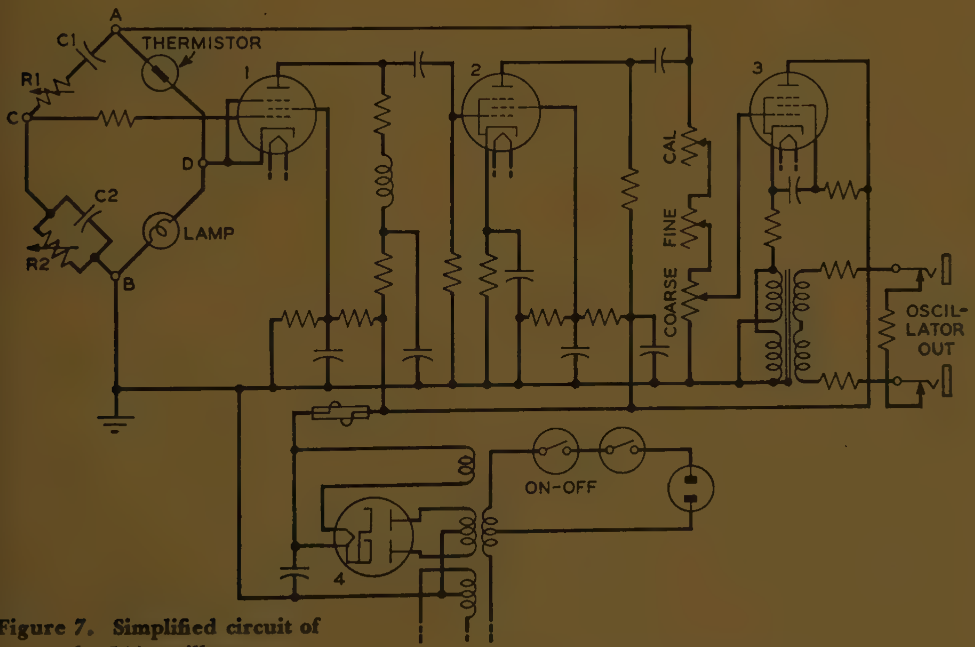

Figure 7. Simplified circuit of the 51A oscillator

The *1AH* tube test set is approximately 12 by 11 by 6 inches and weighs about 25 pounds. Three test sockets are provided to accommodate two *373A* tubes and one *374A* tube, the complement of a *K2* line amplifier. Power is supplied to the set by use of a permanently attached cord and plug which plugs into a standard amplifier power outlet provided on the amplifier bays. This power consists of regulated 60 volts at 60 cycles, 150 volts direct current, and grid voltage for the *374A* tube.

The test set circuits associated with the test sockets allow the tubes to function under conditions very closely stimulating those in the amplifier and include a signal supply circuit obtained from the regulated 60 volts, 60 cycles, a peak reading vacuum tube voltmeter, and various switching and control circuits required to make the various measurements. A simplified circuit diagram (Figure 8) shows the essential parts of the set, omitting other tube test sockets and switching.

The set is calibrated by applying a standard 60-cycle voltage from the signal supply circuit to the vacuum tube voltmeter and adjusting its sensitivity for a standard reading on the meter. Transconductance is measured by applying a known voltage from the signal circuit to the grid of the tube under test and measuring with the vacuum tube voltmeter the voltage developed across a known load resistance. To measure peak plate current voltage which swings the grid to zero bias is applied to the grid by the signal circuit and the peak voltage developed across a known plate load resistance is indicated by the vacuum tube voltmeter. The true peak value is obtained by superimposing an indication of the d-c plate current on the indication for peak a-c swing. The d-c plate current is measured by using the meter as a voltmeter across the known plate load with no input signal applied. By the use of a tap on the filament transformer the filament voltage is reduced ten per cent and filament activity measurements are made. The vacuum tube voltmeter circuit is arranged with a calibrated input potentiometer so that the per cent change in transconductance during a filament activity test is indicated directly on the potentiometer dial.

Grid current is indicated by introducing a large resistance into the grid circuit and measuring the change in direct plate current that results. To measure the maximum power capability of the *374A* tube, a load resistance is inserted in the plate circuit which causes the tube to operate on a dynamic load line whose value of plate cur-

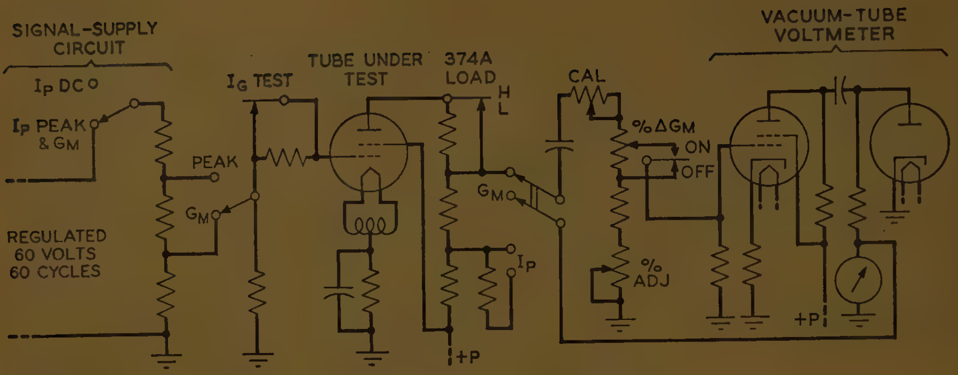

Figure 8. Simplified circuit of 1AH tube test set

rent at zero bias grid swing corresponds to that obtained in the amplifier. The power output under this condition is indicated by the peak voltage developed across this load.

Testing Methods. The *K* system is provided with alarms to indicate abnormal operating conditions. Alarms from normally unattended stations are carried to stations where attendants are located. These alarms check failure of fuses, high or low voltages of batteries and a-c supplies, power failure, and automatic transfer to alternate equipment when provided.

In general, the only tests made on the *K* carrier system on a routine basis are tube tests and checks of the voltage of the grid bias batteries. Alternate sockets have been provided in the amplifiers so that a spare tube may be placed in parallel with a working tube, after which the working tube may be removed for test without interrupting service. The principal improvement in tube testing methods is that dynamic tube characteristics are measured rather than the d-c characteristics previously measured. Laboratory experience has indicated that dynamic characteristics are superior to d-c characteristics in indicating the condition of a tube and its probable future performance.

More elaborate tests are necessary when the system is reported in trouble. These tests include noise and modulation observations at the terminals, pilot level measurements, and modulation tests at various repeaters of the system. The over-all voice-to-voice gain and noise tests made at the terminals give some information as to whether the system as a whole is in trouble or whether the trouble is limited to a single channel.

When a system appears to be in trouble, the first tests to locate the section in trouble are pilot level measurements. These may be made without disturbing transmission as mentioned previously by making bridging measurements with the *31*-type transmission measuring set. Measurements are usually made at attended stations first to locate the section in trouble if this is possible.

X-Raying Oil Fields

A method of X-raying oil fields by remote operation from its research laboratories has been developed by Gulf Oil Corporation. The new development helps solve the riddle of how oil flows through the sand and rocks under any particular field, and how it is affected by underground water and gas.

Since X-raying entire oil fields at their sites would be impractical, the fields were brought to the laboratory. Small 3-inch by 1-inch samples, or cores, from the drill holes are made to reproduce in miniature the layer of rock or sand from which they were taken. Reactions studied within the samples give a picture of flow conditions in a stratum perhaps hundreds of feet thick and miles in extent.

To make such studies, the core is subjected to artificial pressures and saturations of oil, gas, and water. The progress of these elements in the core is gauged by an X-ray device for determining permeability-saturation. The X-ray beams follow the reaction by means of an opaque tracer mixed with the liquid or gas.

First step of the researcher is to establish a basis for comparison by studies of the core at 100 per cent and at zero saturation. Then an extensive series of flow experiments, reproducing conditions which might be created by various recovery methods, must be made.

Effects of gravity, capillary attraction, and the amounts of oil, gas, and water already in the sand are charted. These procedures must be repeated sometimes on as many as 10 or 11 cores taken from the different layers through which the well extends.

By correlating such data, the laboratory can determine how natural pressure, or artificial gas injection, or water flooding will move oil through various strata of the field being studied toward well shafts. Operating methods can be planned accordingly to assure the greatest yield, and the extent of the yield forecast.

Permeability-saturation determination by X rays represents an extension of the electrolytic model oil field technique developed for predicting generalized oil field behavior and guiding placement of wells.

Power Supply for Resistance Welding

A Co-operative Approach

H. WATSON TIETZE
MEMBER AIEE

Co-operation among the electrical utility, the welding equipment manufacturer, and the industrial user is the prime condition for a satisfactory solution to the power supply problem in the resistance welding field. A discussion of one method of approach to the problem is presented as a contribution to the promotion of mutual understanding among the parties concerned.

PROVIDING an adequate and economical power supply for resistance welding is not only the problem of the electrical utility industry, but it is equally the problem of the manufacturer of welding equipment and of the industrial user of such equipment. Each has a definite responsibility. The equipment manufacturer must supply the following:

(*a*). A machine with efficient design characteristics, that is, one which will perform the required work with the least electrical demand.

(*b*). A machine adequate to the work to be performed, but not a high cost, high excess capacity machine.

(*c*). Frank and complete basic electrical data.

(*d*). Full operating and maintenance instructions.

The industrial user's responsibility lies in

(*a*). Installing plant wiring of ample capacity and designed for low voltage drop.

(*b*). Designing the workpieces for minimum electrical demand.

(*c*). Consulting with the utility before machine purchase.

The utility's responsibility is

(*a*). To supply adequate capacity and voltage at the customer's meter.

(*b*). To design the external supply system for minimum over-all cost to the customer and the company, and for minimum disturbance to existing customers.

It is the purpose of this article to promote mutual understanding by detailing and discussing a currently used method of approach to proper power supply for welding, the method developed being based on experience and a close reading of many articles in the technical press (see reference list).

THE VOLTAGE DIP PROBLEM

Many electric distribution systems regulate voltage by induction or step voltage regulators installed in substations. Such regulators have mechanical limitations and cannot follow instantaneous changes in load. The instantaneous voltage dip which results from suddenly applied load therefore is limited only by the resistance and reactance of the supply system from generator to the customer's equipment. This is equally true in those cases where voltage regulators are not used by the utility. Most motors, because they have high inrush currents at low power factors, cause voltage dips on starting. In the resistance welder the voltage dip is intensified, because of the single-phase nature of the load, and the increased frequency of the voltage dips leads to further complications.

MANUFACTURER'S DATA

Obviously, if the demand of the machine is unknown, the supply system cannot be designed and the voltage dip produced cannot be calculated. If the frequency of voltage dip is unknown, it cannot be determined whether the voltage dip will prove objectionable. For an intelligent and equitable solution, the electric utility requires the following data on the proposed welder:

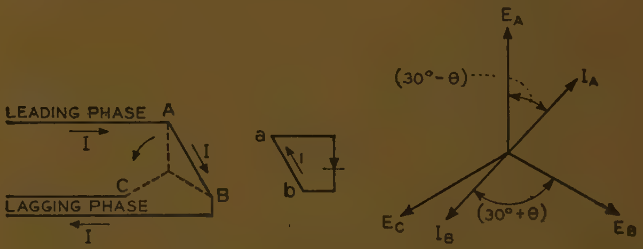

Figure 1. Vectors for single-phase load connected phase-to-phase

For 30 per cent power factor load $(30°-\theta)=42°\ 30'$ *lag*
$(30°+\theta)=102°\ 30'$ *lag*

(*a*). Maximum short-circuit current at the welding head, with the machine throat set at minimum spacing.

(*b*). Maximum open-circuit voltage on highest voltage tap.

(*c*). Approximate working demand in kilovolt-amperes.

(*d*). Approximate working power factor.

Essentially full text of a conference paper presented at a conference on power supply for resistance welding during the AIEE winter meeting, New York, N. Y., January 27–31, 1947.

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Table I. Primary Volts Dip Per 100-Kva Single-Phase Load

Phase-to-Phase and Delta-Delta Connections

Power Factor	Leading Phase		Lagging Phase	
	In-Phase Drop	J Drop	In-Phase Drop	J Drop
100	$20.9R-12.1X$	$20.9X+12.1R$	$20.9R+12.1X$	$20.9X-12.1R$
40	$19.4R+14.3X$	$19.4X-14.3R$	$-2.7R+24.0X$	$-2.7X-24.0R$
30	$17.8R+16.3X$	$17.8X-16.3R$	$-5.2R+23.5X$	$-5.2X-23.5R$

(*e*). Cycle of operation, including length of each weld in electrical cycles and number of welds per hour.

(*f*). Whether synchronous timing or heat control is to be used.

(*g*). Heat control setting to be used normally.

The product of the short-circuit current and open-circuit voltage, as defined in the foregoing, is the basic maximum demand of the machine and this value is used in all calculations. If basic data on the machine are not available, the kilovolt-ampere demand is estimated as three times the kilowatt rating of the machine. If, of course, the welder is available for test, the open-circuit voltage readily can be obtained, and the short-circuit current can be determined by the use of a pointer-stop ammeter and a clamp-on current transformer.

Power factor is not a critical element of most calculations and generally is assumed as 30 per cent for machines rated 50 kw or more, and 40 per cent for machines rated more than 10 kw but less than 50 kw.

MATHEMATICAL ANALYSIS

Working from the manufacturer's data, the following must be determined next:

(*a*). Voltage dip to be experienced on the substation bus.

(*b*). Voltage dip to be experienced on the 4-kv primary circuit adjacent to the customer.

(*c*). Voltage regulation at the welder terminals.

(*d*). Size of transformers required to serve the load.

For the purposes of this article, "voltage dip" is defined as the reduction in voltage appearing between the primary phase wire and neutral on the 4,150-volt 3-phase 4-wire system, that is, that reduction which will appear across 2,400-volt lighting transformers nearby. Voltage dip normally is expressed on a 120-volt base, which is equivalent to primary volts dip divided by 20. "Voltage regulation" is defined as the reduction in voltage appearing at the 240- or 480-volt terminals of the welding machine, and normally is stated in per cent.

The necessary calculations are not difficult, although they can be made so. The simplified method which will be described requires only simple arithmetic. It is applied here to a 4,150-volt 3-phase 4-wire primary system.

Vector diagrams of single-phase loads supplied from 3-phase circuits are shown in Figures 1 and 2 and cover the recommended transformer arrangements of a single transformer connected phase-to-phase (in this instance a 4,150-volt unit) and three transformers connected Y-delta. In each instance the load supplied is of 30 per cent power factor.

The full formula for voltage drop is

$$E=I(\cos\theta-j\sin\theta)(R+jX) \qquad (1)$$

of which the component in phase with the sending voltage is

$$e_1=I(R\cos\theta+X\sin\theta) \qquad (2)$$

and the component in quadrature with the sending voltage is

$$e_2=jI(X\cos\theta-R\sin\theta) \qquad (3)$$

Indicated on the vector diagrams are the angular displacements between corresponding phase voltages and currents for a 30 per cent power factor load.

For a 100-kva load, the term I is equal to 24.1 for both $A\phi$ and $B\phi$ in the phase-to-phase arrangement and in the Y-delta instance is 27.8 for $A\phi$ (referred to as the "loaded" phase) and 13.9 for $B\phi$ and $C\phi$.

Substituting the current and angular values in equations 2 and 3, for 30 per cent and other power factors, gives Tables I and II, in which voltage dip values for a 100-kva load are expressed in terms of R and X.

In most instances the in-phase dip computation will suffice, but until experience is gained it is well to compute both the in-phase and quadrature dips and compute the absolute dip from the formula

$$\text{Absolute voltage dip}=2{,}400-\sqrt{(2{,}400-\text{in-phase dip})^2+(\text{quadrature dip})^2} \qquad (4)$$

Tables III and IV give resistance and reactance values on a 2,400-volt base of representative sizes of substation regulators and reactors, of distribution transformers, underground cable, and of open wire at various spacings.

Table V is important and deserves special consideration. As explained in an article by E. S. Seeley[1] the current in a wire, through the medium of the magnetic field, has an effect upon the effective values of resistance and reactance of all adjacent wires. With relatively large single-phase currents drawn by welding machines, the

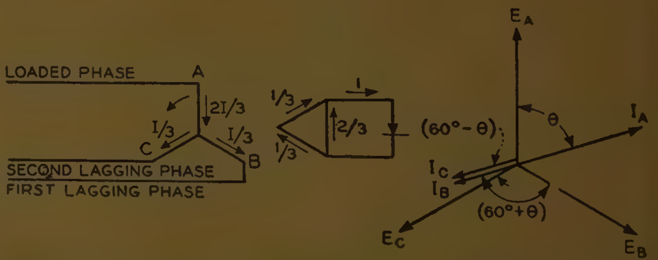

Figure 2. Vectors for single-phase load supplied by Y-delta transformer bank

For 30 per cent power factor load $\theta=72°\ 30'$ *lag*

$(60°+\theta)=132°\ 30'$ *lag*

$(60°-\theta)=12°\ 30'$ *lead*

Table II. Primary Volts Dip Per 100-Kva Single-Phase Load

Y-Delta Connection

Power Factor	"Loaded" Phase		First Lagging Phase		Second Lagging Phase	
	In-Phase Drop	J Drop	In-Phase Drop	J Drop	In-Phase Drop	J Drop
100	$27.8R$	$27.8X$	$7.0R+12.0X$	$7.0X-12.0R$	$7.0R-12.0X$	$7.0X+12.0R$
40	$11.1R+25.5X$	$11.1X-25.5R$	$-8.2R+11.2X$	$-8.2X-11.2R$	$13.8R+1.5X$	$13.8X-1.5R$
30	$8.0R+26.5X$	$8.0X-26.5R$	$-9.4R+10.2X$	$-9.4X-10.2R$	$13.6R+3.0X$	$13.6X-3.0R$

resistance constants are unaffected, but the changes in reactance constants are quite marked and neglect of this fact will lead to serious computation errors. Table V lists the "exact" reactance for open wire of 38.8-inch equivalent spacing (utilizing end pins on an 8-foot 6-pin crossarm, wires arranged *AB-CN*).

To determine the phase to neutral voltage dip, it is necessary only to add the constants of the system to the 4-kv substation bus (on a 2,400-volt base) and the constants of the equipment and conductors on one phase wire of the distribution circuit. The totals of resistance and reactance at any point in the circuit entered into the expressions in Tables I and II and multiplied by the welder demand in hundreds of kilovolt-amperes give directly the primary volts dip at that point. Only three rules must be followed in dealing with open wire:

1. Resistance always is taken from Table IV.
2. For the phase-to-phase connection, reactance is taken from Table IV, choosing the value indicated for the actual spacing between the two loaded wires.
3. For the Y-delta connection, reactance of the "loaded" phase is taken from Table V. The constants of the two lagging phases generally are not required; however, their reactance can be approximated by applying to the values from Table V the correction factors of Table VI.

To determine per cent voltage regulation at the secondary terminals of the supply transformer, the following three formulas are used:

Per cent line regulation per 100 kva, phase-to-phase, Y-delta, or delta-delta connection

$$=\frac{27.8(r\cos\theta+x\sin\theta)}{2{,}400} \qquad (5)$$

Per cent transformer regulation per 100 kva, Y-delta or delta-delta connection

$$=\frac{27.8(R\cos\theta+X\sin\theta)}{2{,}400} \qquad (6)$$

Per cent transformer regulation per 100 kva, phase-to-phase connection

$$=\frac{3}{2}\times\frac{27.8(R\cos\theta+X\sin\theta)}{2{,}400} \qquad (7)$$

Constants r and x are those of one phase wire from generator to supply transformer as previously determined, R and X are the constants on a 2,400-volt base of the supply transformer carrying the load current (the "loaded" phase in the Y-delta example), and $\cos\theta$ is the power factor of the load. In the three formulas the value of the expression $27.8\ (r\cos\theta+x\sin\theta)$ as well as of the expression $27.8\ (R\cos\theta+X\sin\theta)$ is identical with that given in Table II by the formula for the in-phase component of the drop on the "loaded" phase, for example, $8.0R+26.5X$ for a 30 per cent power factor load. For complete accuracy this expression would be expanded to the "absolute voltage dip", equation 4, but the added accuracy is unnecessary for most practical purposes.

The size of transformer required to serve a given welder is computed from the formula

$$\text{Kilovolt-ampere rating required}=H\sqrt{\frac{S_1}{S_t}}$$

where

H = kilovolt-ampere demand during load period
S_1 = load period in cycles
S_t = total period in cycles

A 100-kva load on three cycles and off 12 cycles therefore would require a transformer with a continuous rating of 44.7 kva.

The foregoing formula is approximate. The references list sources detailing an exact determination as well as the suggested method where more than one welder is served.

VOLTAGE DIP AND REGULATION LIMITS

Having computed the required supply transformer size, the voltage dip, and voltage regulation for the proposed machine, the latter two items are compared with limits developed by test and experience.

For good practice, regulation at the welder should not exceed approximately ten per cent. Exceeding this limit may affect not only the quality of the weld but the operation of control apparatus as well. As a general rule it has been recommended that the approximate

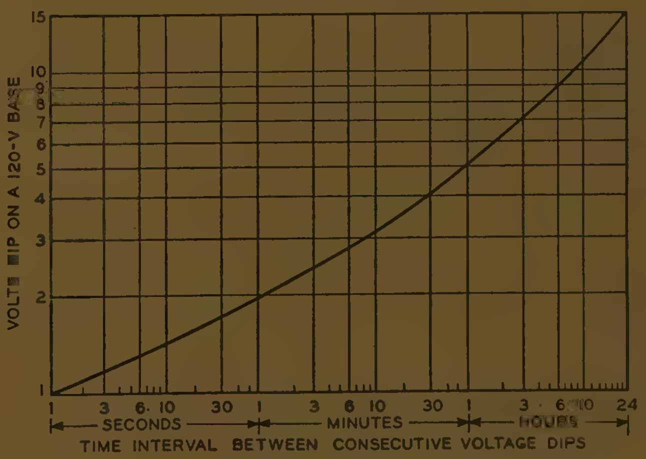

Figure 3. Recommended limits for noncyclic voltage dips

Table III. Electrical Constants

Cable and Equipment
(at 2,400 Volts)

Equipment	Unit	R	X
Substation reactors			
200 ampere, 3¾ per cent	ohms	0.00	0.45
300 ampere, 3¾ per cent	ohms	0.00	0.30
Substation induction regulators			
150 ampere, 10 per cent, single phase	ohms	0.0349	0.2455
300 ampere, 5 per cent, single phase	ohms	0.0087	0.0613
300 ampere, 10 per cent, single phase	ohms	0.0135	0.1193
Cable for 4-kv circuits			
350,000 circular mils, 4/ conductor	ohms per 1,000 feet	0.036	0.033
2/0, 4/conductor	ohms per 1,000 feet	0.094	0.036
Number 1, 4/conductor	ohms per 1,000 feet	0.152	0.037
Distribution transformers			
25 kva (2,400 volt)	ohms	3.59	5.35
50 kva (2,400 volt)	ohms	1.43	3.02
100 kva (2,400 volt)	ohms	0.69	1.90
200 kva (2,400 volt)	ohms	0.31	0.96

apportionment of regulation be

Utility system—four per cent
Supply transformer—three per cent
Customer's wiring—three per cent

The first item, of course, will depend upon the distance from substation to the customer as well as the "firmness" of the distribution system. Where the regulation of the system exceeds four per cent, it often will prove more economical to reinforce the supply transformer by installing paralleling or larger units than to reinforce the distribution circuit. On the other hand, consultation with the customer and welder manufacturer may develop that the anticipated voltage regulation will be satisfactory for the proposed machine.

A voltage dip appearing on the 4-kv bus of a moderately large substation, say one of 15,000-kva load, may affect as many as 16,000 lighting customers. Moreover, the dip may cause hunting of the voltage regulators on the 10 to 15 4-kv circuits radiating from the substation, because the actuating relays normally operate within a tolerance of three quarters of a volt on a 120-volt base. Accordingly, the allowable limit of voltage dip on the substation 4-kv bus is taken as one-half volt. On a large substation this is equivalent to about 400-kva instantaneous demand at 30 per cent power factor.

The computed voltage dip appearing on the 4-kv circuit adjacent to the customer's supply tap is compared with the curves of allowable dip. Figure 3 is applicable to spot, projection, flash, butt, and similar welders. Figure 4 is applicable to seam welders and pulsation welders. There probably should be a separate curve of allowable dip for the pulsation welders for their characteristic welding operation consists of three or four welds in a matter of cycles followed by a rest period of seconds. However, until further data are available, it seems best to use the limits of Figure 4.

Table IV. Equivalent Electrical Constants

Open Wire; Copper
(Ohms per 1,000 Feet, Single Conductor)

	Equivalent Spacing	Number 4*	Number 1	2/0	4/0
Resistance	all	0.257	0.131	0.0821	0.0515
Reactance	12 inches	0.1150	0.1057	0.1006	0.0953
	38.8 inches	0.1418	0.1326	0.1275	0.1222
	64 inches	0.1533	0.1440	0.1390	0.1337
	76 inches	0.1573	0.1480	0.1430	0.1377

* Solid

EXPERIENCE FACTORS

The fact that the calculated voltage dip is in excess of the allowable limits does not necessarily mean trouble. During the war period, when the pressing need was rapid production, many proposed installations, which on calculation gave greater than limiting dips, were approved. Subsequent trouble-free operation, it is believed, was the result of proper selection of an experience factor rather than the greater tolerance of flicker by the public.

The subcommittee on power supply of the AIEE committee on electric welding in 1940 recommended that the demand of a welder should be taken as the short-circuit current with minimum throat spacing multiplied by the open-circuit voltage on highest tap, which quantity has been termed the basic maximum demand of the machine. It is recognized that, while the demand in the first cycle may be equal to the basic, over the total period of the weld the demand will be lower than basic as a result of normal voltage drop in the supply system and the increased impedance of the machine caused by the presence of steel or other metal in the reactance loop of the throat. On the converse, if the machine is energized at other than the proper point on the voltage wave, the resulting transient current, limited only by saturation, may be six to ten times normal. The basic maximum demand formula made allowance, although heavily discounted, for these possibly high transients. However, while these high transients may have a marked effect upon the quality of short duration welds, experience has indicated that, from the standpoint of flicker tolerance, as a general rule they may be discounted completely, and that a further allowance may be made for the effects of normal voltage drop and the presence of the workpiece in the throat. In total, this is equivalent to assuming the maximum demand of the machine as 85 per cent of its basic demand when welding common steel and 95 per cent of its basic demand when welding aluminum.

Most dip-limit curves like Figures 3 and 4 are composites based on tests conducted by the Electrical Testing Laboratories, the General Electric Company, the Edison Electric Institute, and numerous electrical utilities. They seek to record the average reaction of the average individual. Obviously, the reaction of many individuals will be stronger than the average, but this reaction will be modified considerably if the dip-producing equipment

Table V. Exact Electrical Reactance

Open Wire; Balanced 3-Phase Load
(*Ohms Per 1,000 Feet of Single Conductor*)

	Equivalent Spacing 38.8 Inches*			
Phase	Number 4**	Number 1	2/0	4/0
A	0.1361	0.1268	0.1218	0.1164
B	0.1341	0.1248	0.1198	0.1143
C	0.1553	0.1460	0.1411	0.1357

* Conductors arranged *AB-CN* on end pins of 8-foot 6-pin crossarm

** Solid

Table VI. Y-Delta Transformer Connection

	True Open-Wire Reactance in Per Cent of Reactance Given in Table V		
"Loaded" Phase	"Loaded" Phase	1st Lagging Phase	2d Lagging Phase
A	100	49	123
B	100	95	45
C	100	153	149

is on the customer's own premises. On circuits feeding residential areas the curve of Figure 3 should be used, but on circuits which serve only industrial loads as much as a 50 per cent increase may be allowed, depending on the composition of the area. No departures from the cyclic limits, Figure 4, are suggested.

Duration of dip is also a factor. Ten to 15 cycles may be assumed normal. When the process produces a 30- or 60-cycle dip, the tolerance should be reduced moderately.

The allowable dip taken from the curves therefore is modified in actual practice, based on the metal being welded, the composition of the area served by the supply circuit, and the duration of the weld. The application of these tolerances is a matter of engineering judgment.

REDUCING THE VOLTAGE DIP OR REGULATION

The voltage dip produced at a given point by the operation of a welding machine is directly proportional to the impedance between that point and the generating station and the demand of the machine. Only a reduction in either will reduce the dip or lower the over-all regulation.

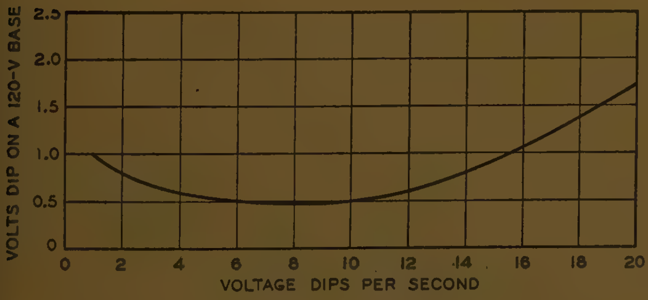

Figure 4. Recommended limits for cyclic voltage dips

The effective impedance may be lowered by

1. Connecting the supply transformer phase-to-phase and utilizing the two phases having the least conductor separation. Where the customer is metered at low voltage, this may require the installation of a second service and meter.
2. Rerouting the 4-kv supply circuit to reduce the length of feed. This often may be accomplished by transferring the load to another circuit.
3. Reinforcing the existing circuit. The effect on reactance, however, is not large, as shown in Table IV.
4. Isolating a 4-kv circuit for the customer's exclusive use.
5. Serving the load from the subtransmission system at 13-kv, 26-kv, or similar voltage. The customer's substation costs, of course, will increase materially.

If the voltage regulation on the secondary side of the supply transformers is too great for proper machine operation, larger transformers will reduce the regulation materially; however, this will not reduce the voltage dip appearing on the 4-kv circuit.

The welding demand may be reduced by

1. Redesigning the workpiece or changing the timing.
2. Equipping the welding machine with a series capacitor or with electronically-controlled shunt capacitors.
3. Installing a 3-phase welding machine. The electrical demand of such machines is not only balanced 3-phase of high power factor, but, for the same workpiece, is only a fraction of that required by conventional single-phase welders.

Obviously, the foregoing suggested means of reducing dips and bettering voltage regulation are not the only ones available, but they are the major and most generally applicable methods.

Many customers purchase welding machines much larger than those required by the proposed work. The working demand expected is generally much less than the basic maximum demand, and this working demand may cause dips which are tolerable. However, a future change in product or process, which may require using the full capacity of the machine, constitutes a threat to future good service. In those instances, it is good practice to have the customer agree, as part of the service contract, to a definite plan of action before electrical demand is raised beyond the tolerable limit. Such a procedure will do much to eliminate misunderstandings.

A PROBLEM IN ECONOMICS

A co-operative approach by the manufacturer, the customer, and the utility to their common problems will be facilitated if it is recognized by all that the introduction of resistance welding is not simply the connection of two supply conductors to a machine. Each problem is a complex economic proposition, the major elements of which are

1. The savings which accrue to the customer from the introduction of the welding process.
2. The cost to the customer of reinforcing and rearranging supply facilities on his side of the meter.

3. The possible cost to the customer of equipment which may be required to limit the electrical demand.

4. The cost of reinforcing or rearranging the electrical utility system, particularly in those instances where the customer is located in sparsely populated territory at a point distant from supply sources.

5. The revenue produced for the utility by the welder and by the new supplementary equipment required by the manufacturing process.

The common responsibility of the three parties will not be discharged properly unless there is thorough study by each and mutual discussion when the welding installation is in the proposal stage. For each to take an independent course will lead to the creation of troublesome problems and poor mutual relations. A heavy financial penalty also may be the result.

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Electric Power in the Cotton Industry

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Though the cotton industry ranks among the oldest in the United States, its adoption of electric power has been a fairly recent development, perhaps because long-time use had brought mechanical power to a high degree of refinement. The extent to which electric power has infiltrated cotton manufacturing processes is described here.

COTTON still is "king" among Southern industries, employing the greatest number of people in manufacturing—437,000—with a product value of one and a quarter billion dollars, and providing a farm income of one and a half billion dollars. Of the 1,248 cotton mills in the United States, 75 per cent now are located in the Southern States.

To the electrical industry cotton represents a total of four million connected horsepower with an annual power consumption of nine billion kilowatt-hours. It uses all electrical products from turbogenerators, motors, and lighting to recent installations of radio-frequency heating for yarn twist setting. Most of this has occurred in the past 20 or 25 years, and complete electrification of the industry has not yet been realized.

In early mills relying on water power, the customary method of distributing power was to have one large grooved rope pulley, driven by the water wheel, located in a ropeway at the end or center of the mill. Ropes were run from the large pulley to a line shaft pulley at each floor level, and all of the mill equipment was driven by belts from these line shafts. This arrangement was carried over when large reciprocating steam engines replaced water power.

Electric energy was introduced into the cotton mill to furnish safer and better lighting. Small generators were installed driven from the mill line shaft or from small steam engines. The output of these generators was distributed through open knife switch panelboards to drop cords throughout the mill.

With generators and motors both available, the limitations imposed on floor planning by a common mechanical drive were lifted. This resulted in the water wheels or steam engines being used to drive large generators which supplied electric energy to motors driving short sections of line shafts.

Essential substance of paper 47-33, "Electrification of the Cotton Industry in the South," presented at the AIEE winter meeting, New York, N. Y., January 27–31, 1947, and scheduled for publication in the AIEE *TRANSACTIONS*, volume 66, 1947.

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The next step from a common line shaft drive was installation of individual motors on separate pieces of equipment which allowed still more flexible and more efficient mill arrangement. As a result, in all new mills and practically all old mills, machines now are nearly completely individually driven. The trend to increase machine speed and output still is continuing and resulting in an increasing kilowatt-hour consumption and investment in machinery per employee.

Early in the electrification of cotton mills, 550 volts was adopted as standard for mill distribution and is now standard in approximately 95 per cent of the mills of the Southeast. Despite recent efforts to change this to 440 volts, all new construction continues at 550.

The kilowatt demand of cotton mills varies from 1,000 for small units to approximately 15,000 for the largest groups. Power is brought to the mill at high voltage and there transformed to the mill distribution voltage. Substations are usually power company owned. Formerly a single bank was supplied for the complete mill load, requiring many transformer banks of 5,000 and 7,500 kva, or even larger, with resultant high currents and high short-circuit capacities. Short-circuit interrupting capacity was not always given sufficient consideration, and many present installations do not have adequate protection in this respect. The modern trend is to split up transformer banks into smaller units of 750- or 1,000-kva capacity and feed portions of the load independently, with circuit breakers available for emergency tie-in.

Busses from the transformer secondary carry the power to a switch room and main distribution board located in the mill. The board includes feeders to the various sections of the mill with indicating and totalizing meters. Instead of the manual oil circuit breakers with current limit protection originally used, modern boards use drawout-type air circuit breakers in cubicle construction with both instantaneous short-circuit and thermal or inverse time limit feeder protection.

Modern use of small power transformers usually is accompanied by unit substation construction. The transformer, distribution feeder circuit breakers, meters, instruments, and relays, all are assembled as a factory-made unit. Some mills have progressed further and have the unit substation transformer air-cooled or noninflammable-liquid-cooled and the complete assembly placed inside the mill.

Power distribution from the switchboard to individual motors is made by conduit feeders, with air circuit breaker or fuse feeder protection, though bus duct recently has been installed in a number of mills. Line starting now is used exclusively for even the largest motors, except on applications such as roving frames where a soft start is required. In these special applications automatic step resistance-type starters are used.

The average mill has a connected horsepower of approximately two times the maximum kilowatt demand with the continuous load being nearly equal to the maximum demand. Nearly all mills operate 24 hours per day with two full shifts and one part shift. This third shift is used to balance out bottlenecks.

Mills entirely equipped with individually driven equipment ordinarily have an over-all power factor of 75 per cent to 80 per cent. Those with a large share of line shaft drives average 82 per cent to 86 per cent. Some power companies in the Southeast have very attractive power factor rates, making the installation of capacitors to correct power factor a high return investment, and most such applications pay for the capacitors in one to two years. Other utilities provide an optional penalty which they may enforce if the maximum demand power factor drops below 85 per cent. The majority of capacitor installations are of the distributed type, with small groups of capacitors being connected to feeders or at larger individual motors.

COTTON PROCESSING

Separation of the fiber from the seed by the cotton gin is the first stage of processing, after which the fibers are carried by suction to a baler. A complete gin, including blowers and conveyers, usually is operated by a 75-horsepower wound-rotor motor.

A 500-pound bale of cotton is the standard unit used in records on size of crops, surplus, and manufacturing. The average crop in the United States is 10 or 12 million bales, of which 8 to 9 million bales are processed. Converting the 500-pound bale of cotton fiber to cloth requires approximately 850 kilowatt-hours of electric energy and 100 man-hours of labor.

Though some mills combine all stages of cotton manufacture, it is more common for mills to specialize, and there are yarn mills, cloth mills, and finishing plants. Yarn mills spin yarn from baled cotton for such specific uses as electrical insulation, sewing thread, tire cord, and knitting. Cloth mills, the most numerous type, process raw cotton through the weaving stage. Finishing plants take the woven cloth and wash, bleach, dye, print, fill, and calender, as necessary for the various kinds of cloth in demand. They are separate plants and finish cloth for groups of mills. Their processes involve the use of chemicals, dyes, and large quantities of process steam. Power sometimes is generated as a by-product of this steam, but, with the decreasing cost of utility power, the trend is away from this combination.

MILL DRIVES

Electric equipment with standard enclosures is usually satisfactory, except in the case of motors. Owing to the great amount of free lint, standard open motors will plug up quickly and lose their ability to cool. Most manufacturers, therefore, make a special textile motor with large ventilating openings and smooth surfaces, so that lint will pass easily through the motor without being caught. In the smaller sizes of two horsepower and below, totally enclosed nonventilated assemblies are used. A recent development has been the use of prelubricated sealed ball bearings in textile motors. These bearings do not require any attention, even lubrication, for periods of five years or longer and result in a cleaner mill.

A breakdown of power consumption in an average mill shows the largest share, or about 50 per cent of the total, is used in spinning. The next largest is 20 per cent for weaving. The remaining 30 per cent is divided between opening, picking, carding, drawing, roving, warping, slashing, and miscellaneous uses such as lighting, ventilation, pumps, and elevators.

OPENING AND PICKING

This operation involves breaking loose the baled cotton, fluffing, beating, cleaning, and forming a thin layer about 40 inches wide which is called a lap and collected in a roll. The motors used are 3, 5, and $7^1/_2$ horsepower of 1,160 and 1,750 rpm speeds. They are line-started and usually interlocked in sequence, as the process includes air and belt conveyers which must be protected against overflow.

CARDS

Though conversion to individual motors has commenced, most cotton cards are driven from a line shaft drive with 30 to 50 cards tied to a single line shaft driven by a single motor. Average 40-inch or 45-inch cards require $1^1/_2$ horsepower for normal running. Two problems complicate the use of individual card motors: the requirement of a high breakaway and accelerating torque necessary because of the large diameter and weight of the cylinder and close overload protection which must be provided because of frequent card packing and quick overload buildup. With a $1^1/_2$-horsepower motor, the starting torque must be at least 300 per cent of full load to provide for breakaway and acceleration. Overload relays must permit the long accelerating period of approximately 30 to 45 seconds and still be sensitive to both quick or slow overload buildup. A standard thermal overload device must be supplemented by shunts or a thermostat on the motor itself.

The average cotton card cylinder with its driven pulley operates at a speed of 165 rpm and is driven by a 870- or 1,160-rpm motor. The required power will vary as the square of the cylinder operating speed. Cotton mills contain from 50 to 500 cards, depending on the size of the mill and the quality of yarn being made.

Control equipment is commonly a magnetic or manual line starter with some reversing device, as the card must be reversed for stripping or cleaning.

DRAWING

After carding, the cotton fibers may be combed to eliminate short fibers or go directly to drawing frames. At the drawing frames the fibers are aligned and straightened by means of a series of rolls, each of which runs faster than the preceding one. The rolls are spaced greater than the longest fiber length to effect a further drawing and straightening.

Only a small amount of power is used for this, with floor-mounted gear motors or low speed textile motors driving the frame shafts which operate at 250 rpm, the average requirement being six deliveries per horsepower. Motors usually are line-started.

ROVING

The next operation, roving, combines the required number of fibers for the weight yarn to be made, further draws and slightly twists the yarn, while winding it on large bobbins in preparation for spinning. Average roving frames require 3- and 5-horsepower textile motors with speeds of either 870 or 1,160 rpm. Roving frames must start slowly, as the yarn is yet very soft with no twist, and low strength, and may be broken easily. This soft starting is accomplished either by using a closely applied motor with low starting torque and line starting or a larger motor with primary resistance type starter.

SPINNING

Spinning consumes the greatest percentage of power in a mill. The yarn is pulled by a set of rolls which draw the fibers and feed them to a spindle rotating at high speeds—7,000 to 10,000 rpm, depending on yarn weight. A small traveler which rotates in a ring guide around the spindle acts as a guide for the yarn.

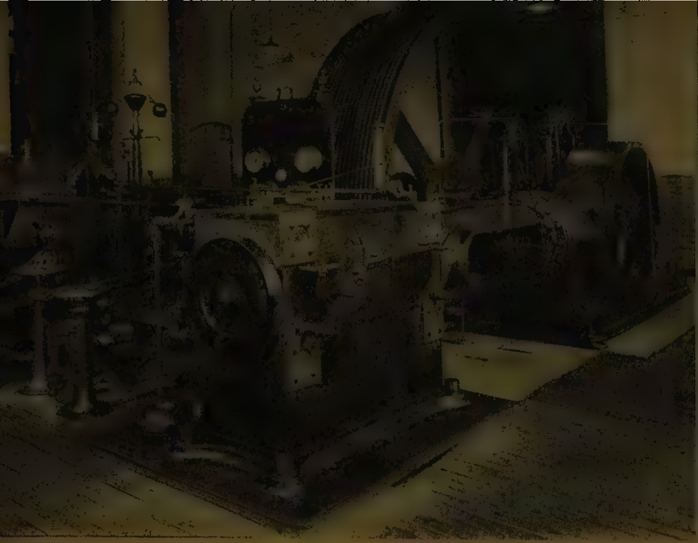
Average spinning frames consist of 200 to 250 spindles. Differences exist in size of bobbins, spindle speeds, and amount of twist obtained. Required horsepowers for individual motor drives range from $7^1/_2$ to 20 at 1,750 rpm with some at 1,160 rpm. Textile-type motors must be used, as the lint content in the air is quite high. Line starting is standard with combination starters mounted on the end of the frame. Required horsepower varies about as the 1.5 power of spindle speed. Other factors affecting the horsepower are ring diameter, amount of drawing effect of feed rolls, and size of yarn.

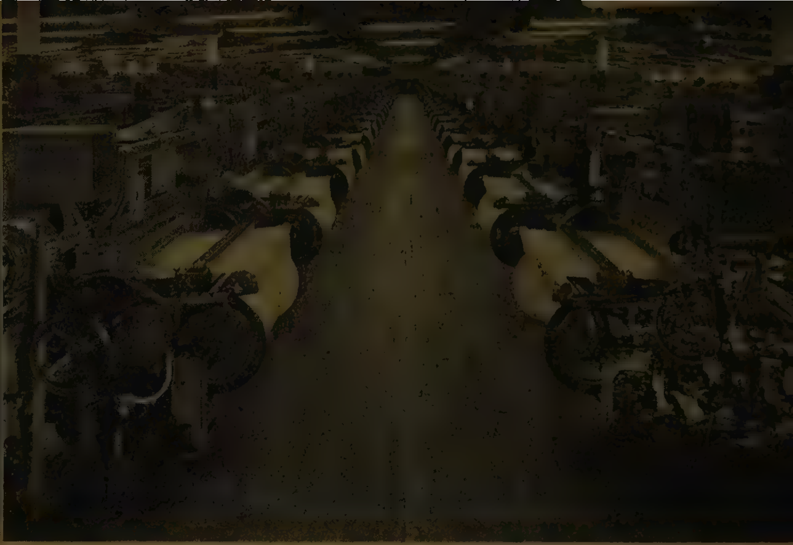
The woof, or cross thread, in cloth is usually lighter and is spun on bobbins used in loom shuttles. Warp yarns are heavier with more twist and are wound on larger bobbins.

Another variation of spinning is twisting which combines and twists spun yarns together to get greater weight or strength. These machines duplicate spinning frames, except that no drawing is included in the feed rolls.

After warp yarns are twisted, they must be wound on beam rolls of approximately the width of the cloth to be woven. The individual yarns are sized, or starched, to give them greater strength and abrasion resistance.

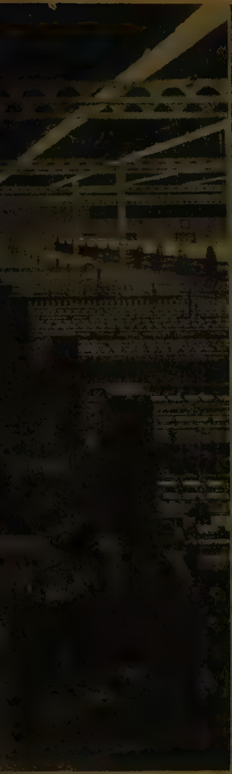
The winding of the yarn from bobbins or spools onto beams is done on a warper. This may be either a drum- or core-type warper, with the first using a constant speed induction motor and the second either multispeed squirrel cage or variable speed direct current. The average

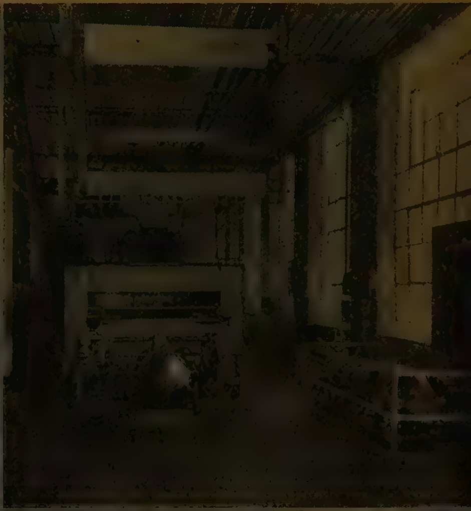




Above: (left) Reciprocating steam engine driving cotton mill by means of ropes to line shafts at different floor levels. (right) A modern weave room installation with individual motor on each loom

Below: (far left) Installation of twisting frames driven by textile motors. (left center) Spinning frame driven by textile motor with special above floor mounting and variable pitch V-belt drive. (right center) Individual motor-driven cotton cards, using chain drive from motor cylinder. (far right) Output end of variable voltage sectional motor drive of cloth-finishing machine, showing last motor and motor generator set with control





Below: (left) Drum-driven warper. (right) Cotton pickers showing cotton lap rolls forming at output end. (lower right) Output end of variable voltage sectional driven slasher with core-driven beam

mill will have 2 to 10 warpers. Motors are three or five horsepower, line-started and equipped with brakes for quick stopping. Drop wires automatically stop the warper whenever a feed thread is broken.

SLASHING

Yarn starching is known in textile terms as slashing, and the machine as a slasher. Any faulty slashing is quite costly, in that it results in excessive loom stoppages with loss of production and lower grading of cloth due to more warp knots. To provide more exacting tension and speed control, a modern slasher drive uses adjustable voltage direct current with sectional motors and a tension-regulated beam windup.

The slasher consists of a stand on which unstarched beams are mounted, a size box with rolls for depositing wet starch on the warp, a set of steam drying cylinders or a hot air drying chamber, a delivery roll for pulling the yarn, and a beam roll for winding up the finished warp. Individual motors are applied to the size box, delivery roll, and the beam in order to provide tension control between them. Because of low driven speeds required, gear motors are used, with floor mounting and driving by chain to their respective rolls. The starch and delivery rolls are 9 inches in diameter, and the beam roll starts on a 6-inch core and builds up to between 24 inches or 30 inches when full. Speeds are four to five yards per minute for creeping and threading, with operating speeds of 20 to 65 yards. Some newer slashers are operated as high as 100 yards per minute. A typical slasher would have a $1^1/_2$-horsepower motor on the size box or boxes, 3 horsepower on the delivery roll, and 5 horsepower on the beam windup.

The beam windup motor must operate over the entire speed range of the slasher, with either an empty or full beam, and maintain constant a preset yarn tension.

A 5/1 speed range motor by field control is used with the shunt field, energized by a Rototrol (rotating regulator). The Rototrol has three fields: a differential pattern field excited from the constant potential exciter and in series with a tension-adjusting rheostat, an accumulative field sensitive to beam motor armature current, and the usual series field to obtain amplification. The Rototrol maintains constant armature current with changing speed by changing the motor field current. This results in varying motor output torque as necessary to maintain constant yarn tension with changing diameter.

The control includes necessary starting equipment for the motor generator set, a motor-operated rheostat to give smooth acceleration and deceleration, tension control stations for each motor, a preset speed control rheostat, and several start–stop–slow pushbuttons.

WEAVING

Basically, weaving has not changed in many centuries, in that a shuttle must be thrown between warp threads alternately from one side to the other. An average cotton mill will have from 400 to 3,000 looms.

The present standard motor drive is an enclosed nonventilated motor mounted on the loom and driving by pinion to a loom main gear with an average of 175 teeth. The motor pinion will vary as determined by loom and motor speeds. For ordinary cloth of weights similar to sheeting, looms will operate at 175 to 210 picks, or shuttle throws, per minute. For heavier goods or intricate weaves, the speed may become as low as 100 picks (for heavy duck).

When first individually motorized, the majority of looms required 1/2- and 3/4-horsepower motors. But at present the 1-horsepower rating is most common, with some $1^1/_2$ and 2 horsepower, and with no new installations below 1 horsepower.

PROTECTION

It is necessary to protect motors from the extremely linty atmosphere in a weave room. As loom motors are small, totally enclosed motors, rather than lint-free, were adopted. These motors, however, are rated at a 40 degrees centigrade continuous rise rather than the usual 55 degrees centigrade. The dual reason for the foregoing is, first, the motor must be able to pull the loom during the breaking-in period, when the great number of new tight bearings cause extra loading; and, secondly, a loom load is of pulsating nature, and the motor losses and heating are higher than for an equivalent steady load.

Early loom motors used standard motor parts which were of low inertia and resulted in the motor passing from motoring to regeneration with each loom pick. Present motors have a more nearly correct balance of motor inertia to match the loom, eliminating the regeneration and increasing motor efficiency.

Individual loom motors are controlled by manual switches at the motor, which include some thermal device for overload protection. Several motors are grouped on a common feeder protected by an air circuit breaker located in a distribution panel. The number of motors tied to one feeder is determined by the size of circuit breaker permitted by the wire used and the thermal capacity of the individual motor starter thermal overload elements. This feeder circuit breaker must hold in when the looms are all line-started simultaneously. With 1-horsepower 550-volt motors, 8 are grouped together on one 25-ampere circuit breaker. This provides a convenient physical arrangement for handling about 50 looms from one panelboard. The feed to this panelboard is supplied through a magnetic contactor to give undervoltage protection and permit starting of the group from one pushbutton station.

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Power Distribution in Textile Plants

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The development of electric power distribution and utilization is not complete although great strides have been made since the days of water wheels. The cotton textile industry continuously is adapting new methods and discoveries to the improvement of production and replacement of existing facilities.

THE record of change and growth in the textile industry, particularly in the South, is tied closely to the history of availability and application of electric power. The first cotton mills were located on water power sites within mechanical transmission distance of the power source. The high atmospheric humidity of such locations also was needed for the proper processing of cotton. The development of the steam engine was the first step made in moving the mills away from streams, though before the use of mechanical air conditioning efforts were made to locate mills in geographical areas of high humidity. The first mechanical air conditioning came just after the development of a reasonably economical steam engine and the industrial migration away from the streams started. In the early days in the South, availability of labor in locations immediately adjacent to the proposed mill was not too much of a factor as it was standard practice to build villages at the mills for the help to live in because towns were small and widely separated as in any essentially rural economy.

As high voltage transmission of power became practical and economical and its availability increased in the South, textile plants began to be built with the availability of labor considered as more of a factor as well as the proximity to raw material supply.

LIGHTING

The first major application of electricity in textile plants was for lighting. Oil lamps and gas lamps were the first lighting means used, but these offered obvious fire hazards in an industry that uses a material which catches fire at a low temperature and burns, when loose and fluffed, at a very high rate. Rather early applications of the enclosed arc lamps therefore were made and this lamp was widely used until about 1912 when the last arc lamps in a southern cotton mill were removed.

Incandescent lamps then were applied and a great deal of trouble was had in getting satisfactory life from the early lamps with their brittle filaments. Pressure from the textile industry and the groups carrying insurance on the mills no doubt hastened the development of the ductile tungsten filament. The textile industry has been quick to adopt the latest lighting developments, and is today one of the important users of the fluorescent lamps and of high-intensity lighting.

ELECTRIC DRIVES

The first completely electrically driven cotton mill on record was put into operation in Columbia, S. C., April 15, 1894. The 17 65-horsepower motors were designed for 550 volts, still the standard voltage used in the textile industry and apparently based on some engineering decision made in the very early days. Alternating current (36 cycles) was chosen; this decision was taken when the a-c–d-c question was productive of violent argument. Many voltages, frequencies, and phase arrangements were tried before the present virtual standardization on 550-volt 3-phase 60-cycle power. The early choices of frequencies were guided in great measure by lamp flicker.

TEXTILE MACHINERY REQUIREMENTS

Four factors have dictated in a large part the development of the present design of textile machinery and its associated electric equipment.

1. Increased production.
2. Reliability.
3. Safety from fire.
4. Ease of installation and maintenance.

The pressure for increased production per hour of operation or per unit of mill area took the form of increasing the operation speed of the machinery and increasing the package size of the product made. There also has been a tendency to cut out as many processes as possible in the path from the bale of cotton to the finished product.

The development of the high-speed loom and the general increases of loom speeds in the late 1920's to middle 1930's changed many weave rooms from belt to individual motor drive, as belt drive has not proved generally satisfactory for speeds above the range of 160 to 170 picks per minute.

Both of these trends increase the amount of power per unit area in the mill and have been factors in increasing the amount of power needed in the textile country. Replacing the textile machinery of 25 years ago with the

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Essential substance of paper 47-103, "Power Distribution in Textile Plants," presented at the AIEE winter meeting, New York, N. Y., January 27–31, 1947, and scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

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machinery of today would increase the demand for power almost 20 per cent in any given spinning and weaving plant.

Reliability. From the standpoint of reliability, pressure from the textile industry was probably not much greater than from other industries, except for the development of small control equipment, sleeve bearings from which oil would not siphon out, and for small motors that would stand shock loadings. The reliability of cables in standard insulations when properly installed has been satisfactory. The mechanical reliability of motors used on individual drives with short centers and rather high belt tensions has been markedly increased by the increasing use of ball-bearings for those motors of this type.

The trend on the protective elements of motor control has swung very strongly to thermal overload equipment designed to heat in step with the motor load and to trip at the safety limit of motor heating. Because much textile machinery is quite long, is set on floors subject to settling, and has many bearings on long shafts, overloads can creep up on motors from slow changes in building alignment. It is much easier to match protective equipment to starting conditions with this type of overload device, a device which is not jammed easily by lint collections.

The matter of a constant power supply is dealt with differently in mills that generate all or a part of their power, and those that buy from a public utility. In those that generate power, a schedule of dropping load either manually or by relays is usually set up; in mills that purchase power the installation of time-delay undervoltage devices is very common, particularly since automatic reclosing breakers have become common on utility systems. These devices enable the production machinery to coast over a failure of short duration. Power failures have different effects on different processes, some of which are more serious and time-consuming than others.

Fire Prevention. The question of safety has been one factor leading to the change of feeder design from open wiring to the present universally used conduit wiring. It also has had its effect on motor control and protective equipment design. If flying lint collects in the control equipment and is kindled by an arc, the ionized gas will help to cause flashover. Control equipment is completely enclosed, thereby preventing dousing from sprinkler heads, water buckets, or fire extinguishers in case of fire. Motors are now designed so that lint cannot collect in them or become jammed between moving surfaces thereby raising its temperature to the kindling point or being exposed to sparks from brush arrangements.

Installation and Maintenance. The present combination line starter with magnetic switch and short-circuit protective equipment installed in the same case is a development coming from the textile industry. This construction offers a number of advantages in ease of mounting and wiring and in ease of replacement of parts. Since textile mills are by nature units containing many similar machines, this development has proved to be logical and has been accepted widely in other industries.

FEEDER DESIGN

The feeders employed in cotton mills followed in general the design of the shafting they in effect replaced. The feeders in the early mills were of radial design, often quite large, and grew longer as the mills grew. Capacitors have been used on long feeders, not only for power factor correction, but also for voltage control. The first wiring was open on porcelain cleats tied to the building structure with lag screws and had slow-burning insulation. The problems of carrying many such feeders through parts of the mills where fires occurred often, and in carrying these feeders from floor to floor of multistory mills often caused installations that were none too safe from the standpoint of fire or mechanical damage. Conduit construction then became standard as it is at present.

VIBRATION

Floor and structure vibration seems to be a unique problem of the textile industry. The looms and shuttle guides throw an oscillating load on the floor which may be transmitted throughout the whole building. This vibration increases and decreases in intensity as the looms in a given area swing into and out of synchronism. In severe cases the wiring in the conduit can be bounced around enough to cause abrasion on the conductor jackets which may lead to grounds on the system at conduit bushings or similar fittings.

The sealing of wiring from the entrance of water should the sprinkler system be actuated is another problem in feeder design.

SWITCHGEAR INTERRUPTING CAPACITY

In the light of modern practice and because of heavier high-voltage backbones on utility systems, the single supply transformer bank, often quite large, usually used in mill work has placed many mills in the position of not having enough interrupting capacity in their switchgear to handle a short circuit on a large feeder.

This change, and the recognition of its consequences, has led the cotton mills to start installation of unit substations fed from a mill-owned 13-kv or 2,200-volt circuit, the feeders being equipped with modern air circuit breaker equipment, usually of draw-out design. This breaker by its speed of action has served to limit the severity and consequent damage of short circuits by decreasing the total amount of power fed into an arc over its duration time, the severity of a failure as a cause of fire being apparently tied rather closely to the total amount of power liberated in an arc and its attendant projection of hot gas out of an enclosure.

CONTROL DESIGN AND DUTY

It is interesting to note the changes in control design that have occurred in the cotton mills. The first application around 1923 of individual-drive control equipment was a direct-operated shipper-rod oil switch. Development has proceeded to the modern combination starter and shipper-rod switch carrying control current only. This type of switch is commonly applied on spinning frames, twisters, and roving frames.

From the standpoint of control duty, some of the cotton mill applications, particularly on spinning frames, are quite severe. In the operation of setting up the spinning frames for removing the full bobbins, an operation called doffing, the motor is repeatedly started while the ring rail carrying the spinning rings is worked down to low elevation. This calls for the magnetic switch to take in the neighborhood of a dozen shots of locked-rotor current, or very nearly this current, within a minute. This is a duty under which older magnetic control and direct-operated control often failed but which the modern contactors handle very satisfactorily.

FLY LINT

Many of the problems concerning the operation of electric equipment in a cotton mill arise from the very characteristics which make cotton a valuable fiber for yarn and cloth. The roughness of the fiber surface and its kinkiness makes fibers cling to each other and form a mat which will increase in thickness if additional fibers float by and touch the surface of the mat. This mat is a good heat insulator. The matting action complicates the operation of any air-cooled apparatus. However, the matting action can be used to make self-building filter layers.

ATMOSPHERE CONTROL

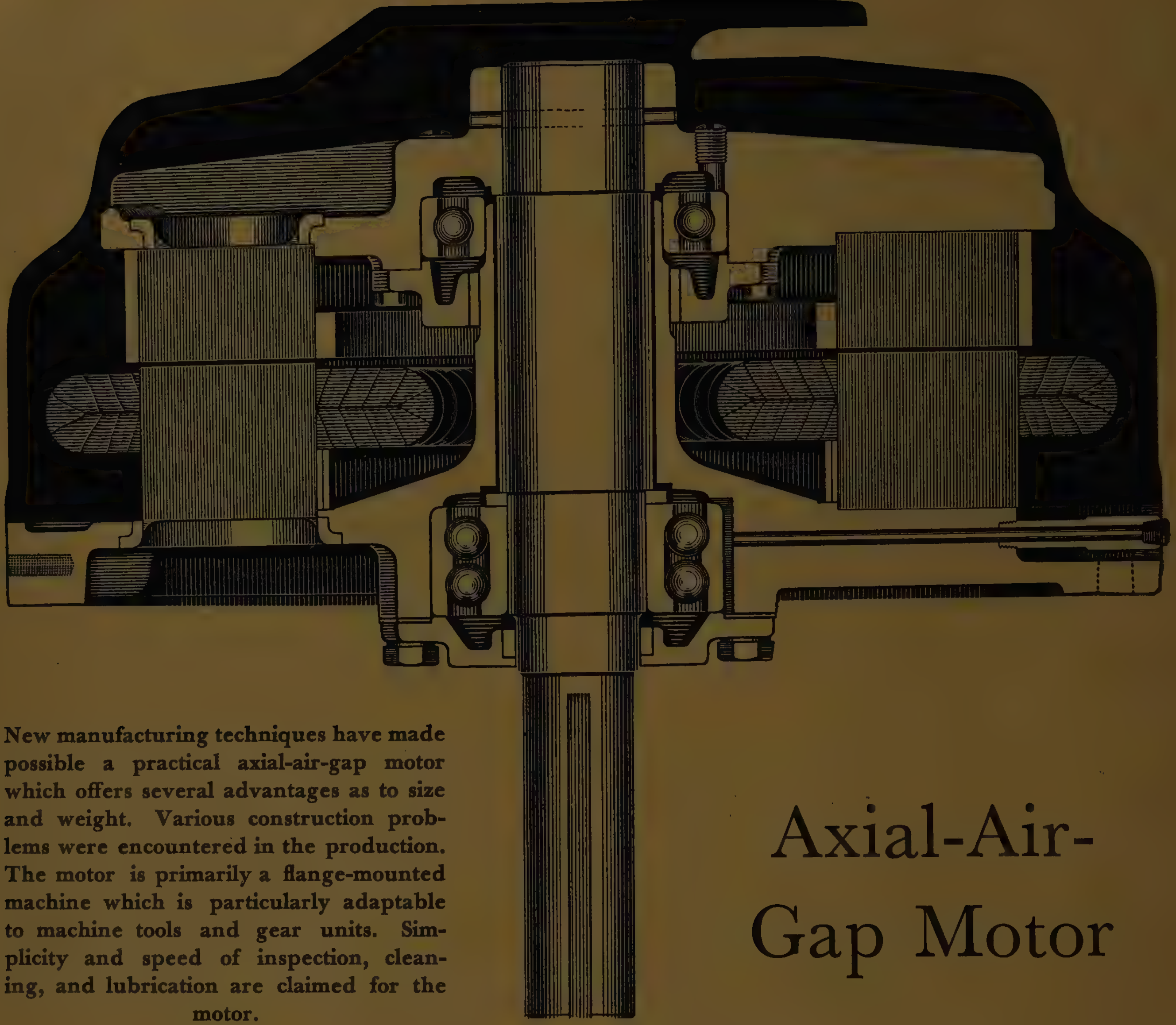
A very small percentage of the power going into a cotton mill goes into actual work done in stretching the cotton or in sliding the fibers one across the other to draft a strand of cotton into a finer yarn. The major part of the power goes to mechanical friction in the bearings of the machines and into whipping the air surrounding a strand of rapidly moving yarn. Practically all the power going into a given area of the mills therefore appears as heat in that area. To hold the fibers contained in a strand of yarn together, it is necessary that the static generated by slipping one fiber over another be kept at a minimum. To accomplish this the humidities in the various departments of the mill running are kept at 60 to 80 per cent relative humidity. To maintain this humidity water is sprayed into the air; the latent heat demand for transforming this sprayed water from the liquid into the vapor phase uses a portion of the heat liberated by the process. If adequate ventilation be maintained through the room and the proper amount of water sprayed it is therefore possible to chill the air in the room by evaporative cooling to a temperature of some 16 degrees above outside wet bulb temperature. With an outside average wet bulb in the summer months of 72 degrees Fahrenheit as exists in the Piedmont section of North Carolina, this gives an average temperature in the room of 88 degrees Fahrenheit. However, some of the synthetic fibers that now are being used require a maintained temperature of approximately 80 degrees in the room under operating conditions. Maintaining these conditions calls for mechanical refrigeration and it is worthy of note in this connection that the design of a mill now under construction calls for roughly 1,000 kw of motor load on the processing machinery and a 400-horsepower motor load from the air conditioning compressor only. This is a development that reasonably can be expected to progress as more information is obtained on economies of operation effected by better temperature control and as employee comfort and efficiency becomes more of a factor. It will bring into the mills motors and control larger in size than have been used previously for manufacturing.

CONCLUSIONS

It appears safe to state that the trend in power usage in the cotton textile mills is upward both from the standpoint of kilowatts per square foot of mill area and per employee. This trend will increase in rate of change as various mechanical limitations to higher speed in the textile machinery are removed by future developments.

The cotton industry is not static in its pressure for development, and other branches of the textile industry are just as aware that there is a constant change in the competitive situation and customer demands. It is also well to note that this industry, which for many years had few technical men working in it, is now a field that recognizes the importance of the engineering and research approach to its problems.

The industry has built few new plants in recent years and for a very long time will be restricted by having to use existing buildings, some of them 75 years old. Some new plants now are being built in a windowless, completely air-conditioned design with the machinery functionally arranged with ease of transport of stock in process as a prime consideration. The full impact of recent developments will probably not be felt for three to five years, but the industry is conversant with such things as infrared and radio-frequency heating, control of static electricity by high-voltage and radioactive ionization, stroboscopic observation and photography, the application of vacuum tube devices for measurement and control of temperature, moisture content, machine speed, and color values. Many more could be mentioned, concerned with what are rather narrow details of the industry's operation, but from the mass of these small changes will come the next great advances.



New manufacturing techniques have made possible a practical axial-air-gap motor which offers several advantages as to size and weight. Various construction problems were encountered in the production. The motor is primarily a flange-mounted machine which is particularly adaptable to machine tools and gear units. Simplicity and speed of inspection, cleaning, and lubrication are claimed for the motor.

Axial-Air-Gap Motor

PRINCIPLES of an axial-air-gap motor are not entirely new, but Fairbanks, Morse and Company of Chicago, Ill., through new manufacturing techniques, has made this design commercially practical.

Coiling steel into a ring and then forming slots by machining is laborious and uneconomical. So it was necessary to design and develop machinery that would punch and coil the strip, and also line up the slots.

Construction of stator and rotor cores was not the only problem in the development of a practical motor. The first motors of this type employed conventional frames and bearing brackets which were difficult to assemble and machining tolerances contributed to inaccuracies of air gaps. Solution was in the development of the so-called "inside frame" in which the supporting member of the stator supports the bearings.

Assembly of the stator and rotor cores to the supporting frame and spider respectively presented another difficult problem. The welding operation invariably distorted the assembly so that it was necessary to remachine after welding. To eliminate this expensive remachining, steel inserts, upon which the cores were welded, were employed to hold the cores in place to cast iron frames and spiders.

The axial-gap motor has a number of features quite different from conventional motors. First and most outstanding factor is the reduction in size. The length is approximately one half that of the conventional motor with a diameter from one to two inches larger. The motor is easy to cool and ventilate because the rotor diameter is large. The axial-gap motor can be inspected, cleaned, and lubricated simply by removing the motor cover, without which it still may be operated.

The WR^2 or flywheel effect of the axial-gap motor is approximately three times that of corresponding conventional motors. This is of particular advantage in applications such as on punch presses where the added

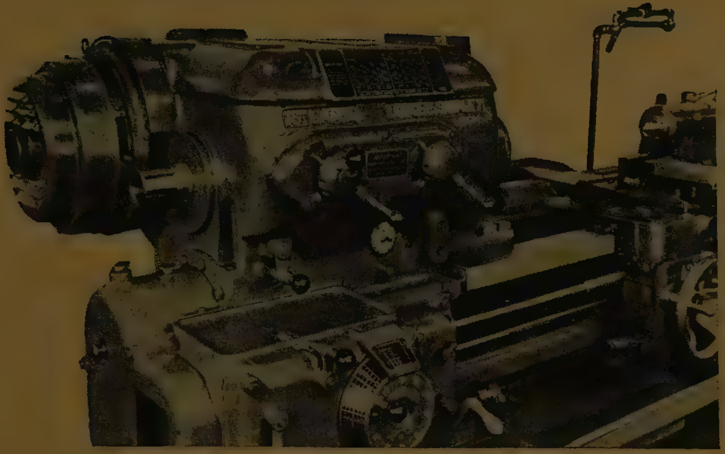


Figure 1. Axial-air-gap 10-horsepower 1,800-rpm motor applied to Lodge & Shipley lathe

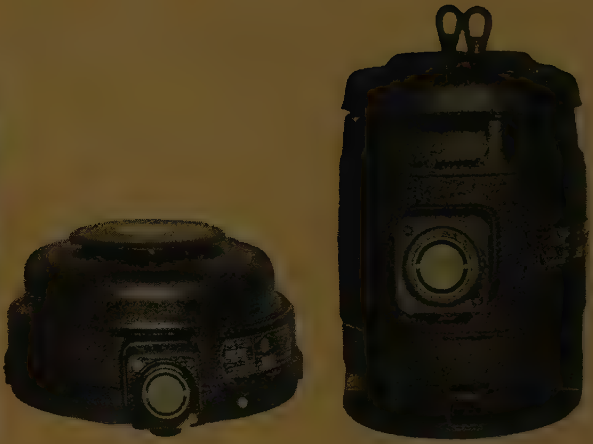


Figure 2. Frame size comparison of conventional and axial-air-gap 5-horsepower 1,800-rpm motors

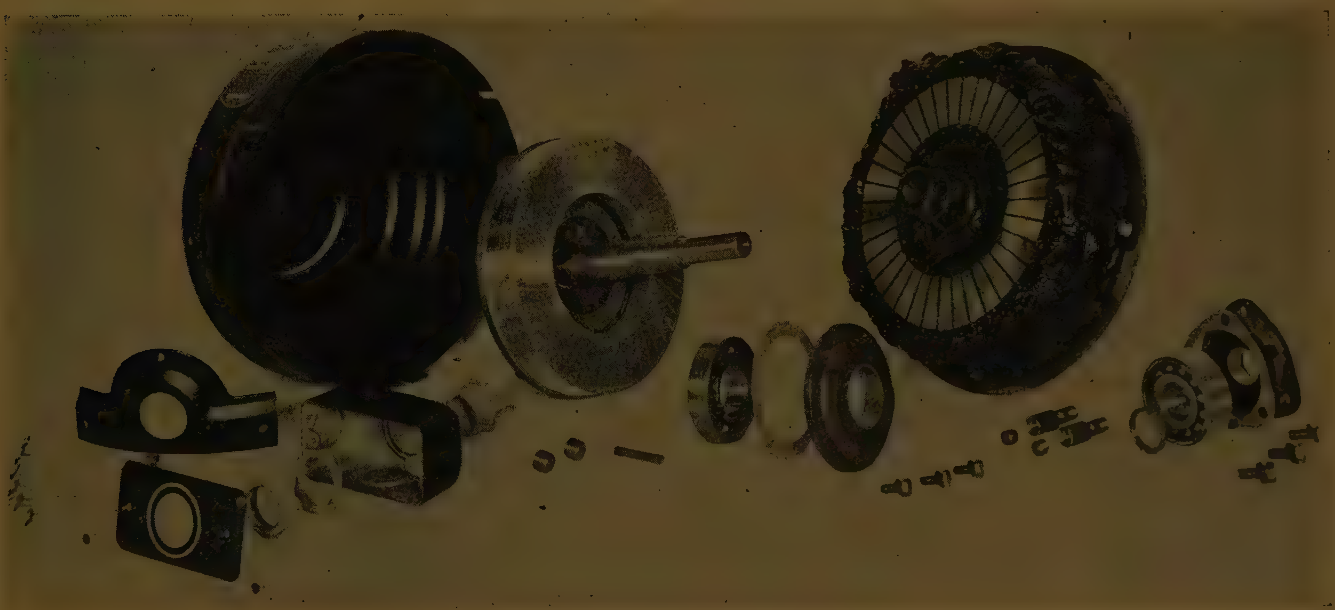
flywheel effect reduces the amplitude of the peak electrical demand by the motor. It is, of course, a decided disadvantage on duty involving repeated plugging and reversing where small diameter rotors are essential and the axial-gap motor should not be used in such instances.

Average thrust of an axial-gap motor is approximately 9–10 pounds per square inch of gap area. Double-row thrust bearings provide a factor of safety of seven or over so that this thrust load becomes a minor factor insofar as the life of the bearing is concerned.

Speed–torque characteristics and operating performance is comparable in practically all respects with conventional motors. Starting, accelerating, and maximum torques are comparable because these are determined by factors that can be incorporated in either type of design. Efficiencies are likewise comparable except that friction and windage losses may be slightly higher with the larger rotor and one thrust bearing. In general, the air gap of the axial-gap motor is a few thousandths of an inch greater than that of conventional motors to provide smoother starting, maximum efficiency, and a more liberal manufacturing tolerance, but slightly poorer power factor.

The axial-air-gap motor is not intended to supersede or displace the conventional motor in general industrial applications except in those cases where it results in a definite advantage to do so. There are many cases of motor applications where the size and shape of the conventional motor is a decided handicap. The axial-air-gap motor makes a better flange-mounted motor, with reduced overhang, and a more accurate mounting. For vertical applications, where height is important, it is claimed to be a "natural."

Figure 3. Dissembled view of axial-air-gap motor



Wood-Pole Line Insulation Tests

P. L. BELLASCHI
FELLOW AIEE

The need for more complete data on the performance of wood, both in regard to impulse and power-frequency operation, has been recognized for some time. Although certain fundamental data are still lacking, much has been learned from laboratory tests about the use of wood as an insulating material. The economic importance of wood-pole line makes these test data valuable assets in the consideration of materials for high-voltage installations.

BECAUSE of the good impulse characteristics wood possesses, it now is utilized extensively as an economic means for providing the necessary impulse insulation strength required of present-day power transmission and distribution lines. Material progress has been made in this field in the course of the past ten years as evidenced by technical contributions and the practical results achieved.

From an engineering standpoint, there is available now a good working knowledge in regard to the impulse characteristics of wood and also a reasonably good understanding of the performance of wood under lightning-stroke conditions. Likewise, the recent findings on the power-quenching characteristics of wood related in this article and the corresponding field observations, all indicate that progress is being made in this direction too. The significance of the experimental results in Figure 1 may be visualized in part from a consideration of available field data. Certain field statistical data relating to 33-kv wood-pole structures specifically state that for insulation clearance (arc-over path) in which an average unit stress of 0.40 kv rms per inch is not exceeded the annual rate of power-arc faults experienced practically reaches an asymptotic value. That is, a further decrease in average unit stress does not appreciably lower the power faults, whereas an increase in the stress to 1 kv rms per inch will more than quadruple the rate of power faults. In Figure 1, an average unit stress of 0.40 kv rms per inch lies in the zone of zero-probability power follow. The foregoing correlation is indicative of the fundamental character of the experimental data.

It stands to reason however that the experimental data on the power-quenching characteristics of wood cannot be projected directly into the application field without consideration being given to the additional influencing factors that are present in actual operation. Of particular importance is the total duration of the stroke discharge. Multiple and long-duration discharges will accentuate the possibility of power follow. Other factors requiring attention are the effect of wind swinging conductors together or toward grounded objects, tree branches falling on the conductors, kites, and so forth.

In applying the experimental data, consideration should be given to the relative frequency of flashover. For instance, an increase in the impulse level of a distribution line from 100 to 300 kv is likely to completely eliminate all flashovers originating from induced voltages and, to that extent, account for improved performance in addition to the betterment resulting from a 3-fold decrease in average unit stress. The foregoing illustrate the necessity of taking into consideration the essential factors of the practical problem, in applying the experimental data.

A criticism that might be raised against the experimental data in Figure 1, and the similar data for the poles, is that the power currents in these tests in no instances attained values above 100 amperes. In this connection, however, the point of fundamental considerations is that the phenomena involved is one of probability of power follow resulting from impulse flashover. The amount of power current that actually may

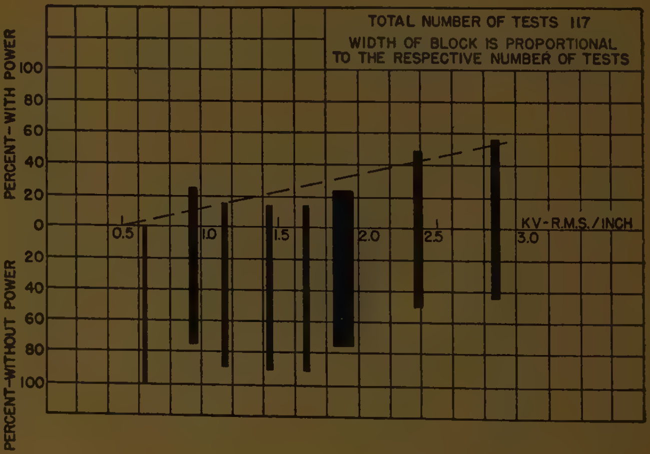


Figure 1. Power follow tests.

Data apply to wood crossarm in combination with four suspension insulators

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Essential substance of paper 47-115, "Lightning and 60-Cycle Power Tests on Wood-Pole Line Insulation," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947, and scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

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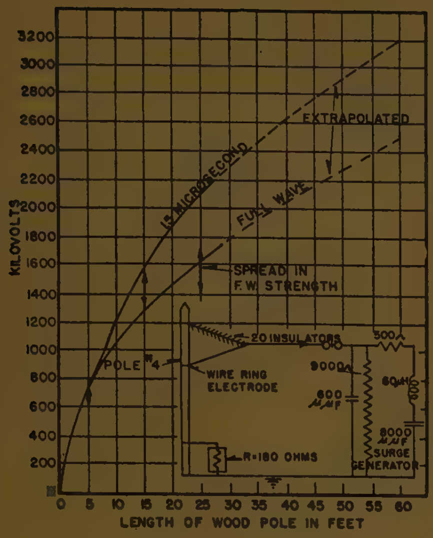
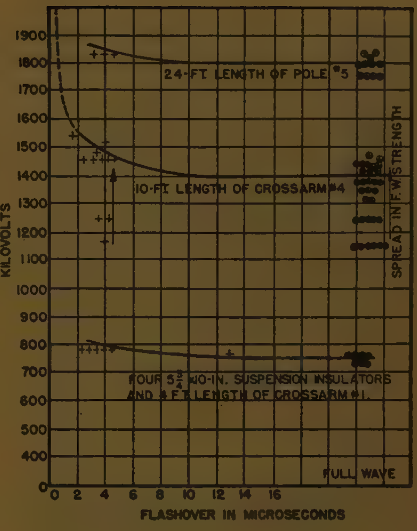


Figure 2. Impulse strength of transmission-line wood poles for various lengths of poles

Tests were conducted in the fall of 1933 on a 60-foot cedar pole with surges $1^1/_2\times40$ microsecond positive polarity, weather ranging from clear to fine rain, humidity—5 millimeters Hg, relative air density—1.04

Figure 3. Volt-time characteristics of typical wood-pole line insulation structures

Tests were conducted in the fall of 1944 with surges $1^1/_2\times40$ microsecond positive polarity, weather ranging from clear to sprinkling rain, humidity—5–16 millimeters Hg, relative air density—1.02–0.95



follow once breakdown is established does not appear to be a determining factor in affecting probability of power follow, provided the conditions of adequate surge current discharge and availability of power voltage are met. Therefore, similar results are expected from tests conducted entailing higher power-follow currents than permitted from the facilities of this investigation.

There can be no question of the desirability of further research and study, both in the field and in the laboratory, on the matter relating to the power-quenching characteristics of wood. In future studies of this character consideration should be given to multiple impulse discharges.

Likewise, the test results on the rate of deionization of power arcs as well as the findings on leakage-current effects emphatically point to the need for additional work in this field. It would seem that the economic importance of wood as an insulator and the means it provides for securing improved operating service would well justify further studies. The results and methods presented here should indicate the direction in which future investigations may be approached to advantage.

Certain conclusions can be drawn from the test and field data accumulated to date:

1. The three predominant factors that determine the impulse strength of wood are the length of wood, the duration of the impulse, and the moisture content in the wood. Other factors are of secondary or little importance.

2. The extent of shattering of wood poles and crossarms from lightning is limited. The amount of damage that may result can be estimated, and if economically justified, means can be provided to reduce such damage.

3. Wood possesses distinct power-quenching characteristics which in a measure now are being utilized with intent by some operators. Experimental data indicate that for an average unit stress of 0.5 kv rms per inch the probability of power-follow is practically zero for single impulse discharge. However, the experimental findings cannot be projected directly into the application field without due consideration having been given to the additional determining factors underlying service conditions.

4. Questions relating to the rate of deionization of the arc as well as the matter of leakage currents deserve further study. In this connection this article presents methods of testing and technique that can be followed to advantage.

IMPULSE STRENGTH OF WOOD-POLE LINE INSULATION

The first impulse tests on wood poles at the Sharon high-voltage laboratory were made in 1933 and are reported in Figure 2. Since that time similar investigations have been conducted on wood poles, wood crossarms, wood guy insulators, as well as on porcelain insu-

Table I. Wood Poles, Wood Crossarms, and Other Line Insulation Structures Tested

Structure	Wood	Treatment	Moisture Content	Comments
Pole *1*	Western red cedar	Butt creosoted	High content	Common distribution-line wood poles
Pole *2*	Western red cedar	Butt creosoted	Very dry	
Pole *3*	Western red cedar	Butt creosoted	High content	
Pole *4*	Western red cedar	Butt creosoted	Normal exposure	Transmission - line 60-ft pole, 18-in. diameter butt, installed in yard in 1931
Pole *5*	Western red cedar	Butt creosoted	Normal exposure	Distribution - line 45-ft pole, 14-in. diameter butt, installed in yard in 1934
Crossarm *1*	Douglas fir	Untreated	Normal exposure	Common distribution-line wood crossarms
Crossarm *2*	Douglas fir	Untreated	Normal exposure	
Crossarm *3*	Douglas fir	Untreated	Fairly dry	
Crossarm *4*	Douglas fir	Untreated	Dry	10-foot crossarm, $3^1/_2\times4$-inch section
Wood-Guy Strain Insulators	Apitong	Creosoted	Dry	8-foot wood guy with 42-in. air gap
Approximately 100 Poles	Cedar, pine, chestnut	With and without	Various	Poles used in lightning-stroke tests

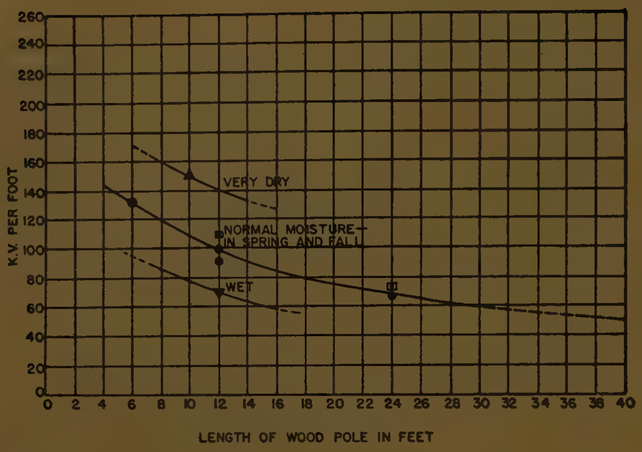


Figure 4 (above). Impulse strength of wood poles as affected by moisture in wood

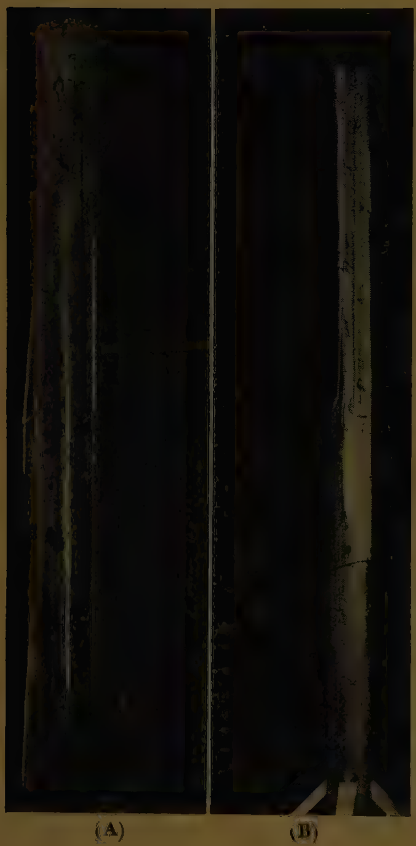


Figure 5. Wood poles damaged by laboratory lightning

lators in combination with wood. A summary of tested specimens used appears in Table I. All the experimental poles as well as the wood crossarms were secured from local utility and are quite representative of line equipment actually used in service. In fact, some of the poles tested had seen service but most of them were new. At the time of test, practically all of the poles were at least one or two years old and in some instances considerably more. Prior to the tests, poles *1* and *3* were outdoors lying on the ground throughout the winter and early spring, and no doubt had a high moisture content. Pole *2* was stored indoors in a warm, dry place and consequently was very dry at the time of test. The conditions of the crossarms ranged from normal moisture content to a dry state. All the tests were conducted outdoors with the exception of the lightning-stroke tests. Figure 3 presents representative volt–time curves for a few of the wood-pole line insulation structures studied. The curves in Figures 2 and 3 clearly show the relationship between length of wood structure and impulse strength.

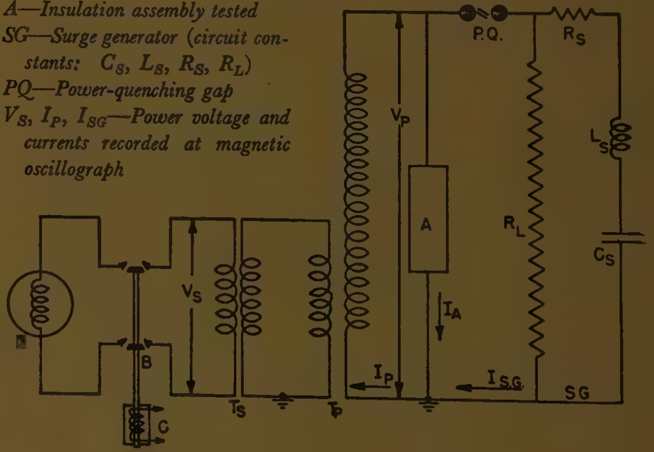
The second factor is apparent from a consideration of Figure 3; the volt–time characteristic of wood is practically flat from 40 to 2 microseconds. Data indicate that for shorter impulses these characteristic curves rise very abruptly.

The effect of the third significant factor, the moisture content in the wood, is clearly brought out in Figure 4. Very dry wood may have an impulse strength 40 per cent higher than that of wood of normal moisture content (12 to 15 per cent). In fact, bone-dry wood may attain a strength comparable to the strength of air. However, when wood such as cedar or fir has been subjected to a wet season or to sustained rainy weather, it can readily suffer a reduction in strength of 30 per cent and possibly even more. When wood is dry even a short sprinkle of rain will tend to lower the impulse strength or to introduce erratic behavior. This effect is indicated in the test data on 10-foot crossarm reported in Figure 3 which were recorded on a dry crossarm during clear weather except for an occasional sprinkle. The low values apparently were the result of this condition. In general more consistent results are obtained when wood is normally dry and in a state of moisture equilibrium with the atmosphere.

Other factors appear to be of secondary importance. Age in itself does not seem to be a factor of importance in determining the impulse strength of wood. For in-

Figure 6. Circuit diagram for combination impulse-power tests on wood-pole line insulation

G—2,000-kva generator
B—Circuit breaker
C—Tripout and reclosing device
T_P*—2,500-kva 230/*$\sqrt{3}$*-13.8 kv, 17.8 per cent impedance transformer*
T_S*—Laboratory transformer for voltage adjustment: 2,000 kva, 1.1 per cent impedance*
A—Insulation assembly tested
SG—Surge generator (circuit constants: C_S, L_S, R_S, R_L*)*
PQ—Power-quenching gap
V_S, I_P, I_{SG}*—Power voltage and currents recorded at magnetic oscillograph*



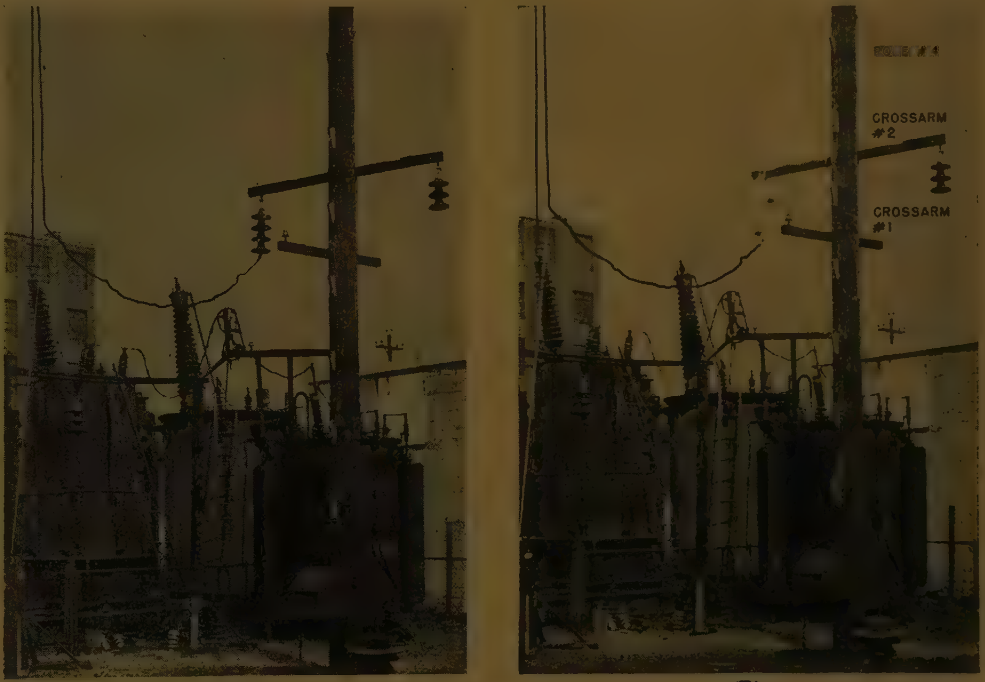
stance, the 12-foot length of pole *4* which was tested in 1933 was retested in 1944 with practically identical results. From those data, in general fir crossarms were found to have a higher unit strength than cedar poles, but this is probably due to the better over-all homogeneity of crossarms rather than to the kind of wood. In connection with wet poles either alone or in combination with porcelain insulators, partial or incomplete breakdown could be observed in some of the tests. Most of the tests were made with positive polarity impulses and the same or higher strength was expected from impulses of negative polarity. However, some of the check tests with negative impulses indicated perceptibly lower strength.

DAMAGING EFFECTS OF LIGHTNING AND PROTECTIVE MEASURES

Since the development of the lightning-stroke generator in 1935, nearly a hundred distribution wood poles have been tested. Most of these poles were western red cedar, and the remainder chestnut and pine. In this test, flashover of the pole is initiated by a very steep-front impulse rising at the rate of 3,000 to 4,000 kv per microsecond, followed in a matter of microseconds by a current discharge of lightning-stroke intensity and duration. The current discharge attained amplitudes of 25,000 to 50,000 amperes and had a total duration of 100 microseconds.

About 20 per cent of the poles were damaged to the extent shown in Figure 5*B*, 15 per cent showed no damage of consequence (as in Figure 5*A*) and the remainder were splintered to an amount not considered too serious. These percentages apply for a single discharge—multiple discharges on the same pole usually accentuated the damage. In addition to testing poles, a few crossarms in combination with poles were also tested. The damage to the crossarms was rather light, however, the number of tests is not sufficient to draw a definite conclusion.

In the field, the probability that lightning currents discharging over poles may exceed 25,000 amperes is less than 50 per cent. Therefore, considering a rate of 50 strokes per annum per 100 miles of line, which is a reasonable figure for Pennsylvania and adjacent central states for 33-kv and 66-kv lines completely unprotected, the laboratory tests indicate that less than a dozen poles in 100 miles of line is likely to suffer damage to the extent shown.



(A) (B)

Figure 7. Impulse-power test applied to suspension insulator string and wood crossarm

A—No power follow. (Note the impulse discharge over the insulators and wood crossarm.) Power voltage = 69 kv rms

B—Power follow. Power voltage = 100 kv rms

The laboratory lightning tests further indicate that wood poles of high moisture content shatter with greater ease than dry poles. Apparently, this has been the experience in the field too. We also observed during the tests that the probability of the wood catching fire is remote unless the wood is very dry and the stroke severe. The presence of a long-duration current component in the discharge, also referred to as "hot lightning," may well accentuate the probability of the wood catching fire.

Lightning-stroke tests were also made on wood-guy insulators in connection with application to wood-pole lines. Out of 15 lightning-stroke applications, two discharged over the wood. However, the amount of damage to the wood (apitong) was not considerable. Experience indicates, and these tests confirm, that for complete protection the horn gap on wood-guy insulators requires a setting of not more than 40 per cent of the wood insulation length and a clearance from horn tip to wood of about 20 per cent the wood insulation length.

POWER-QUENCHING CHARACTERISTICS OF WOOD-POLE LINE INSULATION

In addition to utilizing wood for its good impulse strength, operators have been exploring its power-quenching properties. The field experience and obser-

Table II. Combination Impulse-Power Tests on Two 14$^1/_2$-By-17-Inch Apparatus Insulators and Wood Pole

Test Group	Wood Pole	Positive Impulse Synchronized on 60-Cycle Voltage Wave at: Polarity	Positive Impulse Synchronized on 60-Cycle Voltage Wave at: Point on Wave	60-Cycle Voltage Applied Kv Rms	Number of Tests	With Power Follow	Without Power Follow	Comments
1	Pole *1*, 6-foot length	Negative	55 degrees before crest	67	10	None	10	At 138-kv power-follow current reaches maximum of 70 amperes rms. Currents are proportional to voltage applied*†
				86–90	5	5	None	
				109	5	5	None	
				133	3	3	None	
2	Pole *2*, 6-foot length	Negative	45 degrees before crest	69	4	None	4	This pole had been stored in the laboratory and was very dry*†
				92	4	None	4	
				115	3	None	3	
				138	6	None	6	
	4-foot length			138	3	None	3	
	3-foot length			138	3	None	3	
	2-foot length			138	6	None	6	
	1-foot length			138	6	3	3	
3	Pole *3*, 6-foot length	Negative	55 degrees before crest	69	3	None	3	*†
				92	3	2	1	
				115	3	3	None	
	12-foot length, (4 insulators)			138	3	None	3	
4	Pole *3*, 6-foot length	Negative	Near crest	46	2	None	2	*‡
				69	9	1	8	
				92	5	5	None	
5	Pole *3*, 6-foot length	Negative	Near crest	46	1	None	1	‡
				69	4	3	1	
				92	1	1	0	

Other conditions of tests:

* Power was supplied from a 2,500-kva high-voltage transformer. In test 5, power was supplied from an 18,000-kva transformer.

† $C_s = 0.008$ microfarad and $R_s = 500$ ohms.

‡ $C_s = 0.066$ microfarad and $R_s = 0$.

Table III. Data on Reclosure of Power Circuit Following Clearance of Fault Tests Made on Two 14$^1/_2$-By-17-Inch Apparatus Insulators and Six Feet of Pole 1

60-Cycle Voltage Kv Rms	Reclosure Time*	Number of Tests	Successful Reclosures	Number of Restrikes
92	23$^1/_2$ cycles	5	5	None
109	24$^1/_2$ cycles	5	4	1
133	24$^1/_2$ cycles	3	None	3

* See Figures 10 and 11 for typical oscillograms and method of measuring reclosure time as used here.

vations reported in recent years in connection with wood-pole lines, either designed for or rehabilitated with these objectives in view all lend encouraging support to the possibilities of wood in this direction. As the result, a demand for some fundamental studies on the power-quenching characteristics of wood developed and, to this end, an investigation was undertaken at Sharon.

The circuit arrangement and method of test used are shown in Figure 6. Flashover of the insulation tested was initiated by the surge generator much in the same manner as flashovers due to lightning occur in the field. Simultaneously the insulation was excited at a 60-cycle voltage. Figure 7 shows typical tests. Provision was made to flash over the insulation under test at any point desired on the 60-cycle voltage wave. The magnetic oscillograms in Figure 8 indicate typical cases in which no power current I_p followed the impulse flashover. Examples in which power followed are given in Figure 9.

Oscillograms as well as calculations indicate that the time of recovery is not more than a few hundred microseconds. This value is comparable to rates of recovery usually encountered in service on transmission and distribution systems. Another condition of interest is that there were no limitations imposed due to either the impulse voltages or the current available. In fact, some of the currents used attained intensities approaching lightning-stroke currents.

A total of 117 impulse-power tests were applied to a 4-unit suspension insulator string in combination with various wood crossarms. The effective length of cross-

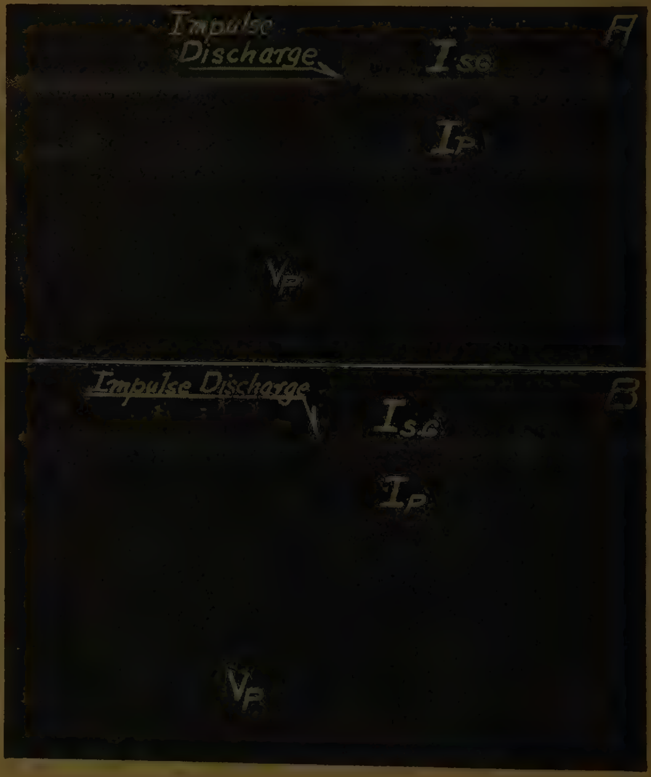


Figure 8. Synchronization of impulse flashover with 60-cycle voltage

A—Preceding the crest of the 60-cycle voltage *B—Following the crest* arm was varied from 2 to 7 feet. Figure 1 indicates that the probability of power following an impulse flashover—for the conditions of test—diminishes to a vanishing point for an average operating stress of 0.5 kv rms per inch. That is, two inches per kilovolt for the discharge path over the wood crossarm and the insulator string should just about limit to practically zero the probability of a power arc following impulse discharge. It can be observed from the chart that increasing the average operating stress to 2.9 kv rms per inch increases the probability of power follow to 50 per cent.

Similar tests were conducted on wood poles in combination with apparatus insulators. The results are summarized in Table II, which comprises a total of 92 impulse-power tests. The behavior of pole *2* is particularly striking in that it shows a zero probability of power follow for a unit average stress as high as 2.6 kv rms per inch. This pole was very dry which may account for this unusually good performance. Each time a test was made it was observed that a sliver of wood the entire length of the section tested would be removed, indicating apparently that the path of the discharge was under the surface of the wood throughout. In all other tests a good deal of slivering was observed. That is, usually a discharge would gouge a sliver from the pole or crossarm, indicating deionizing action. Analysis of the data indicates that for poles *1* and *3* the average stress corresponding to zero probability of power follow is 0.5 kv rms per inch, a value identical to that for suspension insulators and crossarms. At 1.2 kv rms per inch power invariably would follow. It will be well to repeat that these poles had a high moisture content.

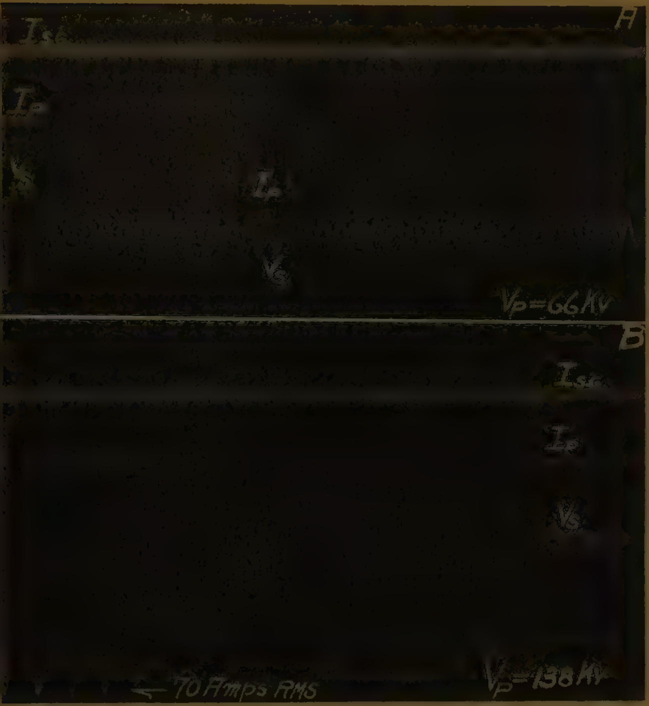


Figure 9. Typical oscillograms of power follow

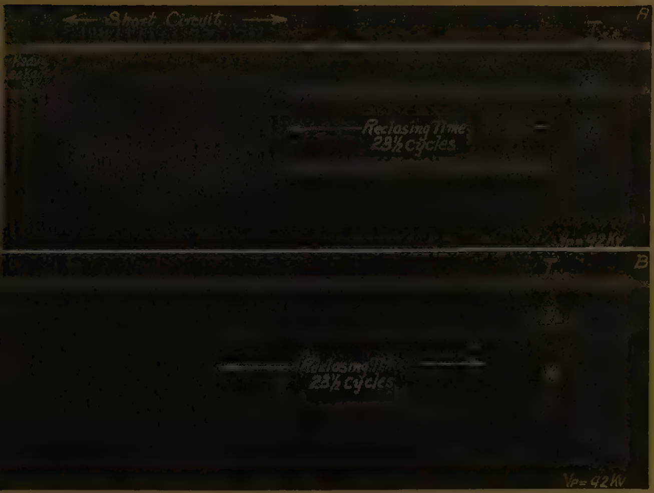


Figure 10. Power follow and successful reclosure

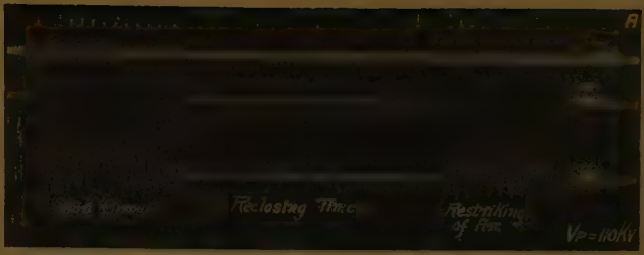


Figure 11. Power follow and restrike of arc

Some tests were made in connection with the reclosure of the power circuit immediately following clearance of the fault. The mode of test is apparent from the circuit arrangement, Figure 6. Following the establishment of the power arc, the short circuit would be cleared and then in a matter of 23 to 25 cycles the power voltage reapplied. Breaker *B* was equipped for this clearing and reclosure operation. The oscillograms of Figures 10 and 11 illustrate the sequence of events and also show typical examples of successful reclosure of the power circuit and of restrike of the power arc. All these tests were conducted on six feet of pole *1* in combination with two apparatus-type insulators, the total path of surface discharge being slightly in excess of 100 inches. The test results are summarized in Table III.

LEAKAGE-CURRENT EFFECTS

The oscillograms of these investigations show that leakage currents invariably occurred when the wood was wet and when the primary (porcelain) insulation was inadequately proportioned with respect to the 60-cycle voltage applied. At no time were leakage currents observed when testing pole *2* and crossarms *1*, *2*, and *3* in combination with their respective porcelain insulators. Leakage currents frequently were recorded when testing poles *1* and *3*, which were wet poles.

A Cathode-Ray B–H Tracer

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The cathode-ray oscilloscope and associated equipment can be used for the quantitative determination of magnetic properties without compensation for end effects. This equipment provides a method not only for obtaining core loss and permeability, but also for obtaining retentivity and coercive force and degree of saturation of the test specimen.

FOR the study of low loss, high permeability steel, having highly directional magnetic properties, it was desired to develop a relatively fast method of property determination which would not require compensation for end effects as is necessary with the orthodox Epstein test of the American Society for Testing Materials.

The magnetic circuit (Figure 1) consists of a yoke made of laminations stacked to give a cross section two by two inches. Four coils are placed on the yoke in such a manner that when they are energized the flux is directed through the test sample. The sample indicated in Figure 1 consists of 29 gauge strips 3 centimeters by 28 centimeters. Seven strips are placed on each side of a rectangular bakelite core and set in the magnetic circuit as in Figure 1*A*, with fiber spacers maintaining a nonmagnetic gap of about 1/16 inch at each end. The gap is included to prevent individual laminations from contacting the yoke and thereby carrying greater flux than those not making contact.

Table I. Comparison of Losses as Determined by Electronic Method and Epstein Test

Material	Peak Flux Density, Gausses	Epstein Test, Watts per lb	Electronic Method, Watts Per Lb I	II	III
A	10,000	0.306	0.312	0.315	0.307
A	15,000	0.740	0.737	0.726	0.726
B	10,000	0.352	0.358	0.358	0.354
B	15,000	0.859	0.87	0.889	0.856

Two coils are used to pick up signal voltages for the electronic circuits supplying the vertical (flux density *B*) set of deflecting plates and the horizontal (magnetic intensity *H*) set of deflecting plates of the oscilloscope, respectively. (*H* in this article includes both magnetization and eddy current components.)

The *B* coil is placed around the test samples equidistant from the ends. The flux linking this coil consists of that through the samples and a negligible amount through the space containing the bakelite core. The voltage induced in the *B* coil is therefore directly proportional to the rate of change of flux, or rate of change of flux density, in the iron. This was found to be uniform over a length greater than that covered by the coil.

The *H* coil is placed in the space enclosed by the test samples, equidistant from the ends. A probe coil showed the flux to be uniform through a section greater than that covered by the *H* coil. Hence, the voltage induced in this coil is proportional to the rate of change of flux, or rate of change of flux density, in the space enclosed by the samples. Because there is no magnetic material in this space, the voltage induced in the coil is also a measure of the rate of change of the magnetizing force, or rate of change of magnetic intensity, over the length covered by the coil.

Because the voltages induced in the coils are proportional to the rates of change of flux density and magnetic intensity, it is necessary to integrate them to obtain voltages proportional to the flux density and magnetic intensity, respectively.

ELECTRONIC CIRCUIT

The electronic circuit for supplying the *B* signal to the deflection plates of the cathode-ray oscilloscope is shown in Figure 2. The *B* circuit contains an integrator followed by two stages of amplification. The *H* circuit is the same except that two additional stages of amplification precede the integrator.

It was found necessary to include the capacitors C_A and C_B as shown. Because the grids of the integrator tubes are coupled to the plates of the preceding tube in the *H* circuit, any sudden fluctuations in the supply voltage appear on the grids of the *6F6*'s with the same polarity, that is as in-phase signals. Without C_A and C_B, those fluctuations are amplified so greatly that the grids of the final stage are driven either positive or to cut-off. By including capacitors C_A and C_B a low impedance path to ground is provided and the in-phase fluctuations do not appear amplified on the grids of the tube following the integrator stage.

Essential substance of paper 47-119, "Quantitative Determination of Magnetic Properties by Use of the Cathode-Ray Oscilloscope," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947, and scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

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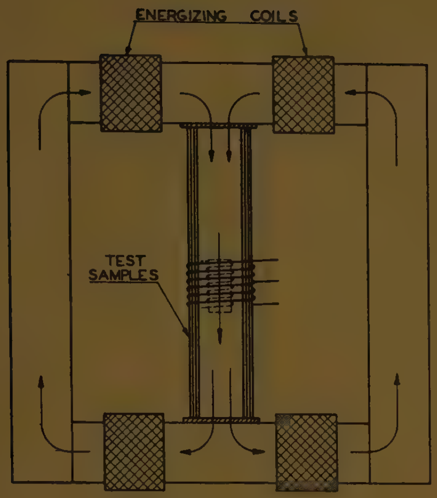
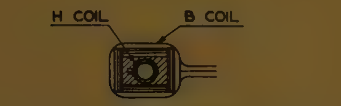


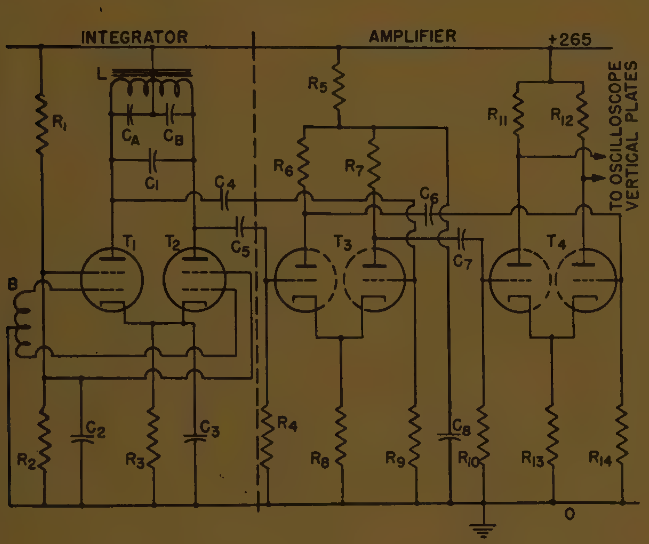
(A) MAGNETIC CIRCUIT



(B) CROSS SECTION THROUGH SAMPLES

Figure 1. Magnetic samples placed in test circuit

Figure 2 (below). Wiring diagram of circuit supplying flux density deflection to the cathode-ray oscilloscope



Capacitors and resistors of one microfarad and one megohm, respectively, are used for interstage coupling. At a frequency of 60 cycles per second the reactance of a 1-microfarad capacitor is 2,650 ohms. Combined with a resistance of one megohm, the phase angle is about 0.15 degrees.

The *H* circuit contains four such combinations, producing a total phase shift of about 0.6 degree. The harmonics are shifted even less. This amount of phase shift may be neglected.

The high value of the time constant of such large coupling capacitors and resistances necessitates the use of an extremely stable d-c power supply. Without such a supply, sudden fluctuations of the supply voltage are transmitted to the plates of the *6F6* tubes by the capacitors C_A and C_B and to the following tubes through the coupling network. The pattern on the oscilloscope screen jumps and then takes a long time before returning to its original position because of the large time constant. At times these kicks come often enough to keep the pattern "dancing" on the screen. It was also found necessary to provide a regulated power supply for operating the cathode-ray oscilloscope. Without regulation, changes in supply voltage caused the size of the pattern on the screen to change.

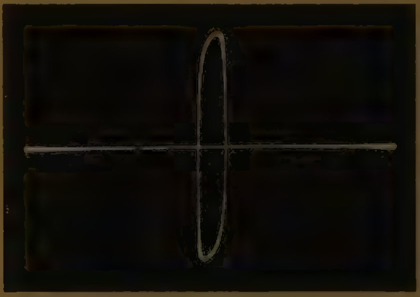
DETERMINATION OF LOSS FROM CURVE

The *H* scale of the cathode-ray screen is calibrated by photographing the line which results when the *H* pickup coil is inserted in the known magnetic field of a cube-surface coil. The *B* scale is obtained directly from the photograph of the core loss curve as the desired peak flux density is set by adjusting the value of the 60 cycle per second voltage applied to the energizing coils on the yoke.

To set the flux density, the voltage induced in a coil wound directly over the *B* pick-up coil is measured with a cathode follower voltmeter which reads average value. The average value of this voltage is a measure of the peak flux density.

Figures 3 and 4 are photographs of core loss curves of the same sample taken with maximum flux density of 10,000 and 15,000 gausses, respectively. It is noted that in Figure 3 the peak of the magnetic intensity occurs ahead of the peak of flux density. This is explained by assuming the core loss curve axes represent flux and magnetizing current. If there were no eddy currents present, the core loss curve would be a true hysteresis loop and

Figure 3. Core loss loop for peak flux density of 10,000 gausses



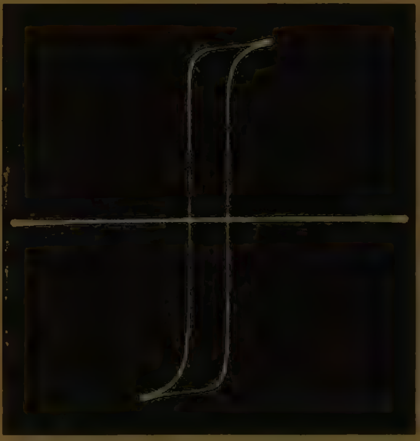


Figure 4. Core loss loop for peak flux density of 15,000 gausses

flux and current would reach their maximum values simultaneously. Since the flux lags the terminal voltage by 90 degrees, the peaks of the flux and hysteresis current would occur 90 degrees after that of the voltage. With eddy currents present, the magnetizing current now consists of a hysteresis current and an eddy current component. The eddy current is set up by the flux and is in phase with the terminal voltage. Hence, the eddy current reaches its maximum 90 degrees ahead of the hysteresis current maximum. At 10,000 gausses for the material tested, the two components of current are of such wave shape and magnitude that their resultant (the magnetizing current) has its maximum ahead of the hysteresis current maximum and, hence, ahead of the flux.

The area of the core loss curve represents the heat loss per cycle per unit volume. To determine the area, the photograph, which is taken on 35-millimeter film, is projected onto an opal glass screen and the area measured with a planimeter. From the screen calibration and the density of the samples, the watt loss per pound is calculated.

Table I shows a comparison of results obtained by the electronic method with those from Epstein tests. The individual tests on each material were not made on the same pieces.

Air-borne Magnetometers

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L. G. PARRATT

L. H. RUMBAUGH

A. J. TICKNER

Developed under the impetus of the submarine menace of World War II, the air-borne magnetometer has found many peacetime uses. Navy airplanes equipped with magnetometers for exploration of Antarctica were used in the recent United States Navy expedition. An expedition now is studying the Aleutian Alaskan volcanos and the Aleutian submarine trench. From there it will proceed to Hawaii and Bikini.

MAGNETIC measurements have played an increasingly important part in geophysical exploration since the 17th century when iron ore bodies were located in Sweden with the help of crude compasses and magnetic dip needles. In recent years magnetic methods have been employed by geophysicists in reconnaissance of extensive areas to designate limited sections for intensive study by more elaborate methods. The presence of certain anomalies in the intensity of the earth's magnetic field often can be correlated with features of the subsurface structure associated with petroleum or minerals. Many deposits of iron ore, oil, copper, and gold have been located with the aid of magnetic surveys.

Until recently magnetic surveys have been carried out on the ground with magnetometers requiring accurate levelling upon a firm base. Mapping of an area has involved correlation of a multitude of discrete measurements at accurately spaced stations. A typical survey employing quarter-mile spacing might proceed at a rate of five miles of contour or about $1^1/_2$ square miles per day in favorable terrain.

During World War II, a magnetic air-borne detector was developed by Bell Telephone Laboratories in co-operation with the Naval Ordnance Laboratory as an outgrowth of means of magnetically finding and tracking submerged enemy submarines.

Employing this air-borne magnetometer, the United States Geological Survey and the Naval Petroleum Reserves have been able to cover as much as 1,000 miles of contour per day over inaccessible terrain. An additional advantage of the aerial method resides in the continuous nature of the record and freedom from the influence of surface magnetic irregularities.

AERIAL DOODLEBUGS

Air-borne magnetometers measure the variation in the magnetic field at the detector as it is moved through space. This variation is recorded as a function of time;

Essential substance of paper 47-104, "Air-borne Magnetometers for Search and Survey," presented at the AIEE winter meeting, New York, N. Y., January 27-31, 1947, and scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

E. P. Felch, W. J. Means, and **T. Slonczewski** are with Bell Telephone Laboratories, Inc., New York, N. Y.; **L. H. Rumbaugh** is with the Naval Ordnance Laboratory, Washington, D. C.; **L. G. Parratt** and **A. J. Tickner,** formerly with the Naval Ordnance Laboratory, are now at Cornell University, Ithaca, N. Y., and the Western Electric Company, Inc., Hollywood, Calif., respectively.

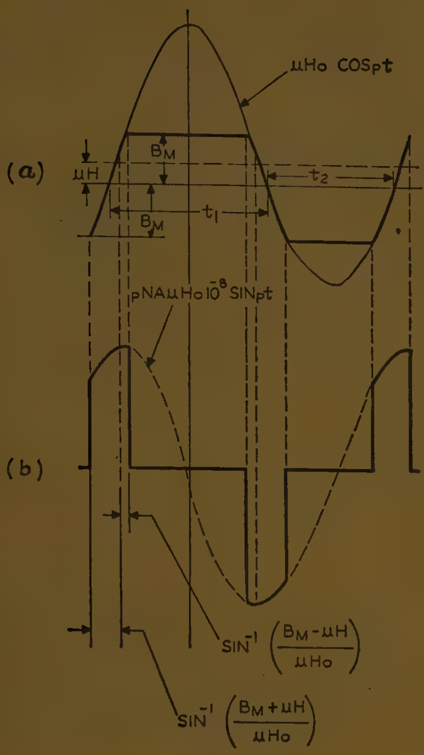

Figure 1

(*a*)—*Variation of flux with time for an idealized B–H characteristic*

(*b*)—*Electromotive force per turn corresponding to variation of flux in Figure 1a*

when the speed of the vehicle is known, and the scales are properly adjusted, the record gives a magnetic profile of the path.

The method of detection consists of placing in the field under investigation an inductor with an open core of highly permeable and easily saturable magnetic material and superposing on the unknown field a sinusoidal magnetomotive force large enough to saturate it. The electromotive force, produced by the time variation of the flux in the core in a winding surrounding it, is then fed into an electronic circuit where its wave shape is analyzed in such a manner as to indicate the magnitude of the field producing the flux. Figure 1 illustrates the theoretical wave shapes. The *ASQ-3* and *-3A* systems use a single frequency, the second harmonic component of the infinite series of voltage harmonics, for detection. While a multifrequency broadband detector utilizes more of the available energy, it presents the problems of broadband amplification and balance for both amplitude and phase. The single frequency system, although using a smaller source of energy, benefits from the simplicity of narrow band amplification, lends itself to a design free from balance requirements in manufacture or in flight, and is adapted to efficient production and inspection methods. It permits the use of a 2-terminal inductor, markedly simplifying the design of the system.

INDUCTOR SENSITIVITY

Assuming an optimum circuit design the sensitivity is limited by the highest impedance which can be maintained at the grid of the first vacuum tube with a satisfactory stability. At constant impedance, the sensitivity increases with the length of the core and is affected very little by its cross sectional area. In a well-balanced design the core length will be such that the magnetic noise at the inductor caused by uncontrollable motions of the inductor in the earth's field and the motion of nearby magnetic objects is somewhat larger than the electronic noise in the detecting circuit. A shorter core would cause the electronic noise to limit the over-all sensitivity. A longer core would increase the size of the equipment at the point where compactness is most important, without simplifying the amplifier design by a worthwhile amount. The 1.5-inch length adopted yields a sensitivity of better than 10 microvolts per gamma (1 gamma $= 10^{-5}$ oersted) at the output of the 2,000-cycle filter. A third source of noise limiting the sensitivity of the instrument, is found in the Barkhausen effect. This is at present, much lower than the over-all noise of the system in flight which is of the order of 0.25 gamma.

CONSTRUCTION OF THE INDUCTOR

Figure 2 shows the construction of typical inductors. A strip of permalloy sheet one mil thick is rolled into a core about 1/10 inch in diameter. The use of the thinnest practicable material reduces the eddy current losses. The rolled core has barely more than one convolution.

Although the sensitivity of the inductor differs little for different materials, the driving power required by the inductor does depend on its choice. The best material was found to be standard *4-79* permalloy. After the core is annealed, it is slipped over a glass tube which is then inserted in a Lucite spool as shown. The spool carries a single winding which is used both to feed the input current to the inductor and to detect the useful output. In static field measuring applications this same

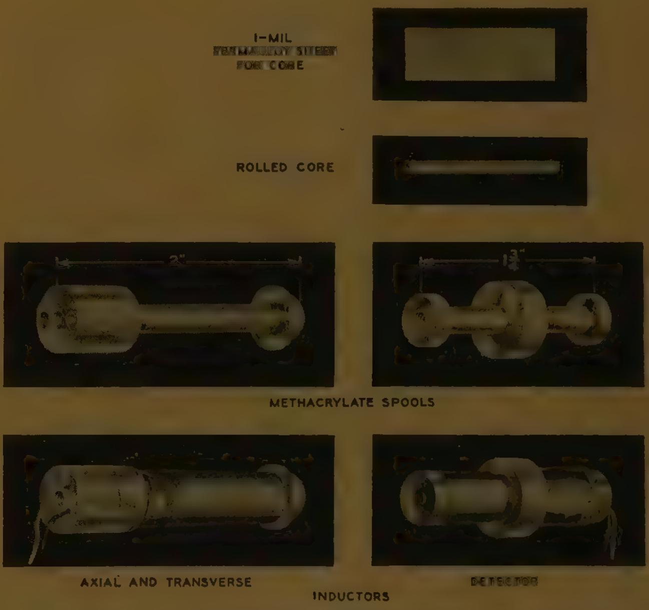

Figure 2. Details of construction of the inductor

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winding also carries the direct current for nulling and compensation purposes.

With the proportions of the cylindrical core as shown, the output of the inductor is independent of the field at right angles to the axis of the cylinder and depends only on the component of the field parallel to it. The inductor has therefore a very definite magnetic axis which coincides with the axis of the cylinder. It is also found that to a sufficient degree for this application the output is proportional to the applied field.

INDUCTOR CIRCUIT

The circuit to which the inductor is connected consists of a 1,000-cycle oscillator which feeds the driving current to the inductor through a filter which eliminates all other frequency components. The current is fed over a long cable as shown in Figure 3 which removes the inductor from the vicinity of the rest of the apparatus and its magnetically disturbing effects. The second harmonic current generated in the inductor returns over the same conductors and is fed into the electronic detector through a narrow pass band filter which eliminates all frequency components except the second harmonic. Each filter offers a high impedance in the attenuation band so as not to introduce an insertion loss to the other circuits. The large capacitance of the cable presented a problem which was solved by absorbing it as a part of the filter configuration

The nonlinearity of the inductor as an inductance has brought about a special filter design problem, since the reactance of the inductor also forms part of the filter network. This difficulty was turned to advantage by designing the input filter as a voltage regulator so as to make the inductor output independent of the driving voltage. In addition, the oscillator output is regulated by an automatic level control. The control voltage is obtained by rectifying the alternating plate voltage of the oscillator output stage.

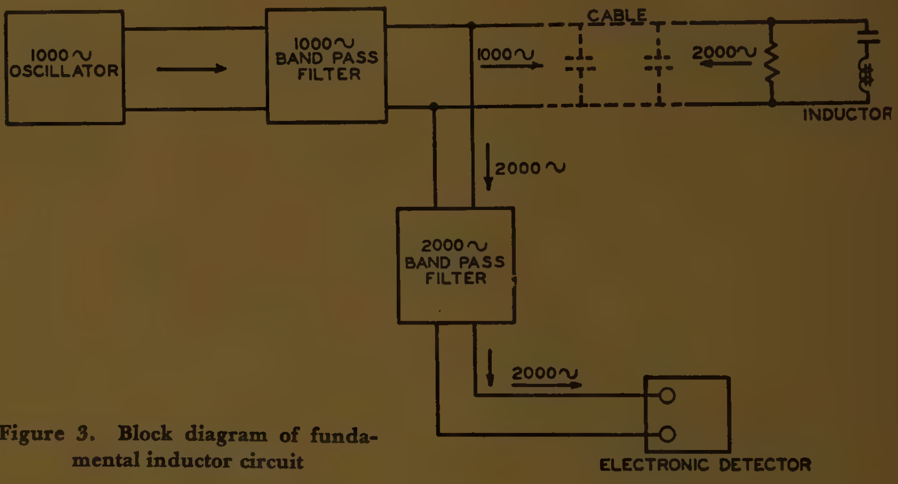


Figure 3. Block diagram of fundamental inductor circuit

ORIENTATION OF THE INDUCTOR

In the design of air-borne magnetometers the proper selection of the inductor axis is a matter of primary importance because the variation $\Delta \boldsymbol{H}$ to be measured is usually small in comparison with the total value of the field. (For example it is 1 in 57,000 near New York, N. Y.) To minimize the stability requirement (on the order of 1/4 degree), the inductor should be parallel to the earth's magnetic field. This principle is embodied in the magnetically oriented detector system shown in simplified form in Figure 4. This employs two auxiliary inductors, T and A, which control servomotors in such a manner as to keep their axes perpendicular to $\boldsymbol{H}$ and therefore the axis of the inductor D parallel to $\boldsymbol{H}$.

Although this is theoretically a perfectly sound system, it is found in practice that it is difficult to build a sufficiently sensitive servomechanism system that does not require adjustment in flight.

One way to avoid the servomechanism difficulties would be to measure a scalar function of the field, such as the square of the field $\boldsymbol{H} \cdot \boldsymbol{H} = H^2$, a quantity proportional to the energy of the magnetic field. Such a system may be built using the fact that the square of a vector is equal to the sum of the squares of the components along three mutually perpendicular directions. If three inductors are mounted with their axes in an orthogonal system, and their outputs are squared electronically, and added to produce an indication proportional to the energy of the field, this indication will be independent of the position of the axis and therefore of the position of the system. A few simple computations show that the requirements for the mechanical alignment of the three inductors, their linearity, and the stability of the squaring circuits, are too severe to be practical, except in the case when the angle formed by one of the inductors with the earth's field is less than two degrees.

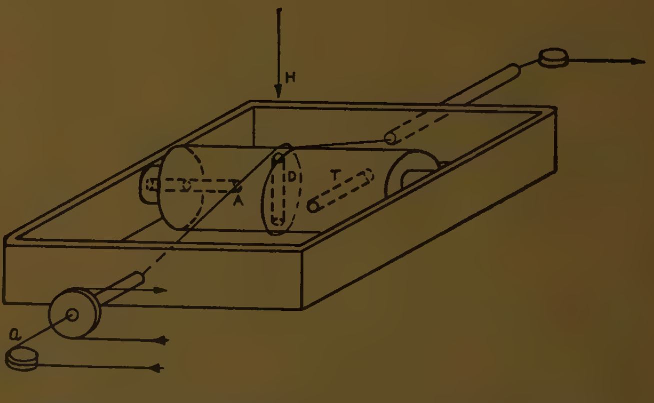


Figure 4. The 3-inductor system mounted on gimbals

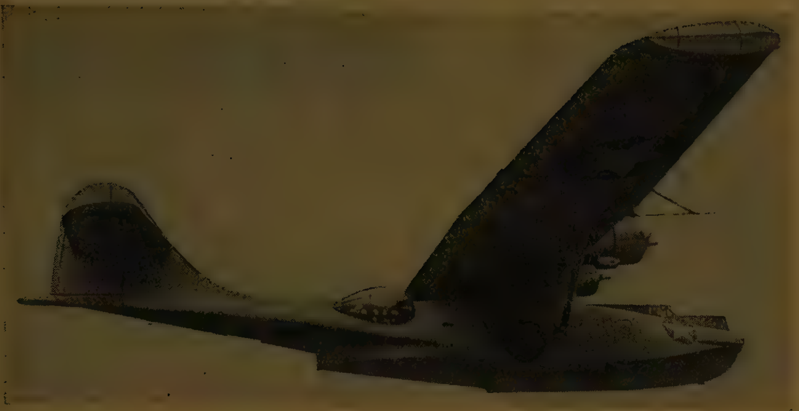


Figure 5A. PBY patrol airplane equipped with plywood tail extension for magnetometer

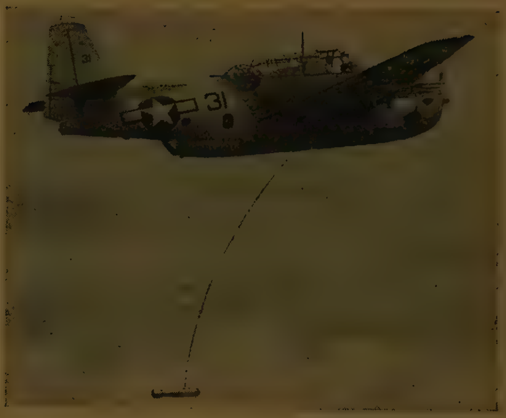


Figure 5B. TBF airplane flying a bird from an underwing cradle

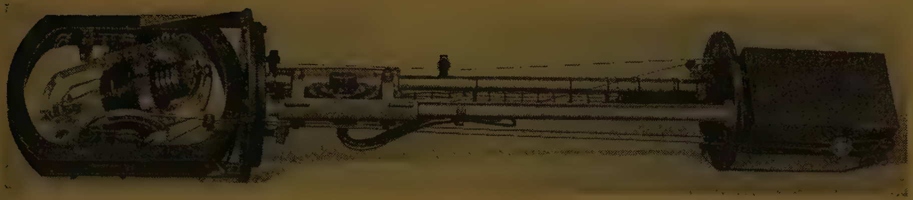


Figure 6. Orienting mechanism

THE *AN/ASQ-3* MAGNETIC AIR-BORNE DETECTOR

The *AN/ASQ-3* magnetic air-borne detector employs a combination of these two schemes. One of the inductors, called the detector inductor, is oriented by means of two auxiliary inductors called axial and transverse, while the apparatus records the variations in the sum of the squares of the outputs of all three. The device may be considered to be a squaring detector with partial orientation to keep it in the most favorable operating position, or a magnetically oriented detector with a compensating system for disturbances caused by small deficiencies in orientation.

Electronic Circuits. Each of the three orthogonal inductor outputs is connected through a 2,000-cycle filter to the grid of a separate vacuum tube. These tubes have substantially parabolic grid voltage–plate current characteristics, thereby producing a combined plate current which has direct current and $4\omega t$ functions of H^2. Either the direct or the second harmonic 4,000-cycle current may be used to obtain a response proportional to the square of the input. The objection to the use of direct current is that it is superposed on the zero input space current of the tube. This not only is large, but also is not very stable. It is affected by variations in the supply voltages, by accelerations, and by the rotation of the tube in the magnetic field of the earth. The 4,000-cycle current is free from these objections.

The outputs of the three parabolic tubes are combined by tying their plates together at the input of a 4,000-cycle filter. This rejects unwanted modulation products and delivers across the low frequency amplifier input a voltage which is proportional to the energy of the field, and, as stated previously, independent of the orientation of the detector in the earth's field. The 4,000-cycle voltage is linearly rectified and the resulting direct voltage is blocked by a capacitor while the low frequency signal passes through an equalizer which determines the frequency response of the detector. The output is recorded on an ink recorder. A meter which may be observed by the pilot is connected in series with the recorder. A control box permits the operator to adjust the sensitivity of the instrument to 10, 25, 50, or 200 gammas full scale. The inputs to the amplifiers which energize the servomotors are in parallel with the inputs of the squaring tubes. The frequency of the 2,000-cycle input signal is lowered to 130 cycles by beating it against a 2,130-cycle oscillator.

Mechanical Construction. The mechanical design of the system is governed by the necessity of preventing magnetic disturbances from reaching the inductors.

The closest disturbing magnetic mass is that of the servomotors which in the interest of good performance cannot be too far from the inductors.

This entire unit called the "orienting mechanism" is located as far as possible from magnetic parts of the plane, particularly the engines. In a large airplane such as the *PBY* sufficient isolation is obtained by mounting the unit in a plywood tail extension as shown in Figure 5*A*. The electronic apparatus is then mounted forward in the airplane. In smaller airplanes such as the *TBF* the unit is housed in a streamlined nacelle, called a "bird," which is towed about 70 feet beneath the airplane as shown in Figure 5*B*. The towing cable, which is less than 1/2 inch in diameter, contains seven conductors which convey the currents to the three inductors, return their outputs, and energize both of the two phase servomotors. The ground conductor of silicon bronze also serves as the strain member.

The Orienting Mechanism. The inductors are mounted in a cylindrical block of cast methacrylate. Because of its homogeneity this material possesses 3-dimensional stability to a satisfactory degree. Four gold-plated phenol fiber slip rings are provided for taking off the connections. Monel metal ball bearings at each end of the inductor mounting fit into beryllium copper pivot screws in a methacrylate inner gimbal which in turn rotates in similar bearings in the outer gimbal frame. Rotation about the two perpendicular axes is effected by 2-cord drive systems one of which passes through the hollow bearings in the outer gimbal ring. This feature, together with the slip rings, permits unlimited rotation about both axes so that under no circumstances can the system become locked.

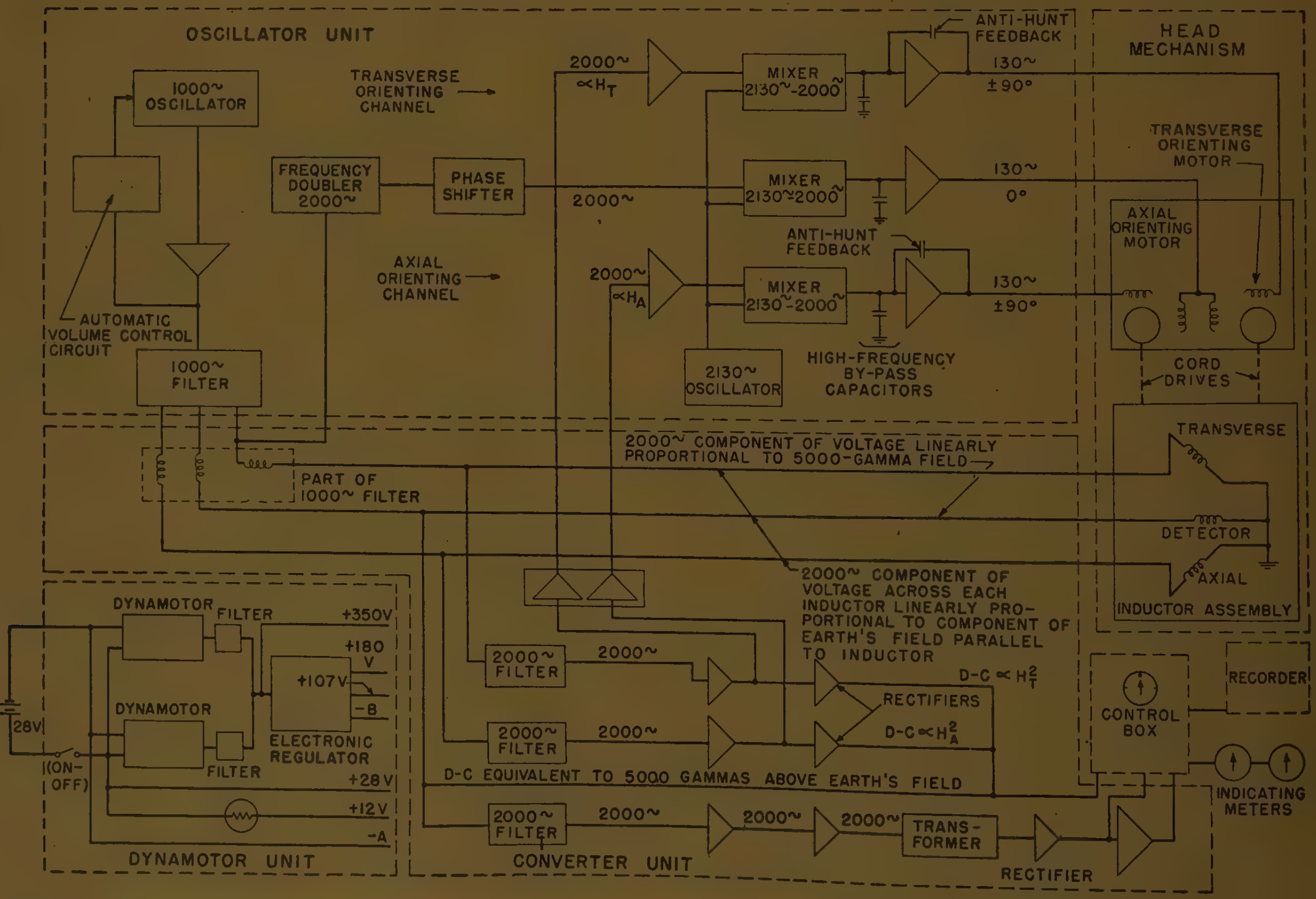
THE *AN/ASQ-3A* SYSTEM

The *AN/ASQ-3A* system, shown diagrammatically in Figure 7, was developed for applications at lower aircraft speeds which required an extension of the frequency range downward. It is capable of measuring changes in static field strength. The basic principles and most of the apparatus units are identical to those employed in the *AN/ASQ-3.* The principal departure in design involves the addition of a control box. In addition to the fine and coarse suppression current controls, the control box includes a sensitivity control and a selector which provides three optional frequency responses. The lowest extends the response downward to direct current, while the other two insert blocking capacitors which obviate the necessity of frequent suppression current adjustments at higher aircraft speeds.

The magnetic field in the detector inductor is reduced to approximately 5,000 gammas by a direct suppression current flowing in the inductor winding. This direct current is obtained from a dry cell battery and a calibrated current control network in the control box. The 2,000-cycle output of the detector inductor which is linearly proportional to this 5,000-gamma residual field is amplified and linearly rectified. This rectified voltage is amplified in a d-c amplifier and applied to the recorder and indicating meters. Hence, as long as the suppression current remains constant, the recorder and meters indicate changes in the magnitude of the earth's field.

In contrast with the *AN/ASQ-3* the sensitivity of this system is independent of the field strength. The suppression current may be adjusted by controls to permit

Figure 7. Block diagram of the AN/ASQ-3A system



operation in ambient fields of 25,000 to 75,000 gammas.

The squaring arrangement for compensation of small angular motions differs considerably from that used in the *AN/ASQ-3*. The 2,000-cycle outputs of the axial and transverse inductors are amplified and rectified by parabolic rectifiers. The output currents of these rectifiers which are proportional to the squares of their inputs are subtracted from the suppression current in the detector inductor. While this compensation method is based on an approximation, it is entirely adequate for angular departures up to two degrees. A series resistor ganged to the coarse suppression current control serves to proportion the compensating current to the ambient field.

THE AIR-BORNE MAGNETOMETER FOR GEOPHYSICAL EXPLORATION

The air-borne magnetometers which have been used by the United States Navy and the United States Geological Survey of the Department of the Interior for geophysical exploration are modified *AN/ASQ-3A* systems.

In geophysical applications the instrument measures changes in the absolute magnitude of the earth's magnetic field. To obtain the desired precision of plus or minus one per cent plus one gamma for measurement of changes in field, it is necessary to maintain the suppression current to better than 0.01 per cent in spite of wide variations in ambient temperature.

The *AN/ASQ-3A* system is provided with a special control box for geophysical use and the converter unit is slightly modified. Advantage is taken of the fact that a maximum sensitivity of 50 gammas full scale is adequate compared with the 10-gamma full scale sensitivity of the *AN/ASQ-3A* to introduce additional feedback at several points in the circuit. This improves the stability of the converter with respect to supply voltage changes and mechanical shock.

The suppression current is derived from a large $22^1/_2$-volt dry battery in a thermally insulated portable box. To insure stability a constant current of 700 microamperes is drawn continuously from this battery. By preaging this battery and maintaining its temperature above 50 degrees Fahrenheit, it is possible to reduce the current drift to less than 0.01 per cent per hour over a useful battery life of over six months.

The noise level of the geophysical instrument in flight is less than one gamma. Instrument drift is less than 10 gammas per hour and the accuracy of measurement of field changes is in the order of one per cent. In practice it has been found that this performance is ample for magnetic mapping even in areas of low magnetic gradients.

Detecting Impurities in Uranium

Thirty-three impurity elements, some in concentrations as low as one part in 20 million, have been detected and estimated through a modified spectrographic method developed at the National Bureau of Standards and used since 1942 in the Manhattan Project for analysis of uranium and its compounds.

Impurities differ in their effects on the nuclear chain reaction. Some elements such as boron and cadmium may interfere if present in concentrations as low as a few tenths of a part per million, and many other elements should not exceed a few parts per million. Rapid, sensitive, and accurate methods therefore are required for the determination of at least 60 chemical elements in a variety of uranium-base materials. Established spectrographic methods of analysis are unsuccessful because of interference by the complex uranium spectrum in which more than 20,000 lines have been observed.

This difficulty was overcome by separating the impurities from the uranium in the carrier-distillation method by converting the uranium sample to a refractory compound having low volatility (the black oxide of uranium U_3O_8) and distilling the impurities from this compound in a d-c electric arc.

In order to sweep out the minute quantities of impurity vapors from the sample without volatilizing the uranium, a small amount of a volatile material, termed a "carrier," is added to the sample. Gallium oxide was found most useful as a carrier and is added at a concentration of two per cent in the uranium oxide. When the mixture is heated by a d-c arc in a carbon electrode of special design, the carrier material and impurities are volatilized into the arc. The uranium, remaining as a residue, can be recovered readily from the electrode—an important consideration, particularly with some active forms of uranium. The light of the arc, examined with a spectrograph, provides a spectrum consisting of the simple spectrum of gallium plus the spectral lines characteristic of volatile impurities in the uranium.

For quantitative determinations, carefully prepared standards of known composition are submitted to the same treatment as the samples. Amounts of impurities are then estimated by photometric measurement, or by visual comparison of the spectrograms of samples and standards. Determinations are made to an accuracy of plus or minus 10 per cent of the amount of the element present. For example, boron and cadmium can be observed easily at a concentration of 1 part in 10 million, and the concentration can be determined to within one tenth of this amount. The greatest sensitivity, observed for the detection of silver, was 1 part in 20 million.

Progress in Light Sources

Developments in light sources since and before World War II have been extensive, and the effect of light on the total field of view of human vision is being considered more and more in artificial illumination. Incandescent light sources, which include arc and filament lamps, and vapor discharge sources, which include metallic vapor discharge and hot- and cold-cathode fluorescent lamps, have many different characteristics which make them suitable for various applications, but no one type of lamp is suited for all purposes.

LIGHT is one of the environmental stimuli and it is related to the others (heat, moisture, air movement, sound, and so forth) for which optimum conditions previously have been established. The natural luminous environment has been said to contain the clue to desirable artificial lighting practice as well as to expose the close dependence of man, for safety, upon the degree to which he is adapted to the prevailing stimulus pattern of the total field of view. Work has been done which shows that the race literally depends upon light for its continued survival. Light for some time has been considered principally in its relation to the cones of the eye with little regard to the rods and their function in alerting the individual to his environment. Because the great majority of artificial light is produced for human seeing, an examination of the stimulus pattern and the sensitivity of the eye are important. The illumination of the sun on an object is approximately 10,000 times as great as that produced by a candle at one foot from the object. It is claimed that artificial illumination levels above approximately 200 foot-candles with good distribution are not warranted because human vision does not detect enough improvement past this point to justify an increase in intensity.

Light having a wave length of 5,560 angstroms, a yellow-green light, produces the maximum response in the human eye. For the dark-adapted eye the response curve shifts toward the red end of the spectrum. Under dark-adapted conditions, the fovea, a region predominantly made up of cones, is sensitive to red light where the parafovea, a region predominantly made up of rods, is insensitive to color, especially to red (Figure 1). With this information in mind the suitability and adaptability of various light sources can be evaluated to some extent.

The purpose of any lamp is to convert some form of energy into visible radiation. The usefulness of a lamp depends, not only upon the efficiency with which it converts the input energy to radiation, but also upon the suitability of the produced radiation for the particular

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Based upon conference papers presented by R. G. Slauer, Sylvania Electric Products, Inc., Salem, Mass.; H. C. Rentschler, Westinghouse Electric Corporation, Bloomfield, N. J.; and R. N. Thayer, General Electric Company, Cleveland, Ohio, at the symposium on limitations of light production during the AIEE winter meeting, New York, N. Y., January 27–31, 1947.

application involved. To be useful as light, radiant energy must fall within the region of the spectrum to which the human eye is sensitive. Although the ultraviolet and infrared regions of the spectrum immediately adjacent to the visible are not directly useful for illumination they are increasing in importance for other uses, and "lamp" and "light source" have been extended by common usage to include sources of near-visible radiation.

The visible spectrum includes electromagnetic radiation having wave lengths from approximately 4,000 to 7,000 angstroms, or in frequency from 750×10^{12} to 430×10^{12} cycles per second. Calculation indicates that theoretically perfect conversion of electric energy into light of 5,560 angstroms, the radiation producing maximum response in the human eye, would produce about 620 lumens per watt. It must be emphasized that this mechanical equivalent of light applies only if the light is of one wave length. Different color radiations produce psychological effects worth considering. Blue and green, the predominant colors in mercury discharge lamps, are said to be cool colors which do not flatter human complexion. Orange and red are said to be warm colors and are predominant in the incandescent lamp. A balanced spectrum of white, such as might be produced by the sun (whose output varies seasonally), limits the luminous efficiency possible to approximately 300 lumens per watt.

CARBON ARC

The electric sources of light may be classified as incandescent and discharge types. Included under the incandescent classification is the carbon arc which has three modes of operation, low intensity with neutral-core carbons, low intensity with flame-supporting-core carbons, and high intensity. The low intensity arc operates on comparatively high voltages (3,700–4,000 volts), and produces extremely bright white light from a small source in the positive crater. The flame arc makes use of positive carbons having cores of different composition which produce different color arcs having lengths of radiation for use in therapeutics, photochemistry, irradiation, and as artificial sunlight. The high intensity arc has a low voltage, high current characteristic producing brilliance as high as 130,000 candles per square inch. Luminous efficiencies vary from 10 to 80 lumens per watt.

Advantages of the carbon arc are: very high output of radiant energy, flexible quality of emission, close approximation to sunlight, uniform quality and intensity, output unaffected by age, high brilliance, and concentrated source. These qualities are utilized to the greatest extent in photography and the related work of projection. Disadvantages of the arc are its production of fumes, necessity of replacing carbons, large amount of heat produced, necessity for an arc stabilizing ballast because of a negative volt-ampere characteristic, and an arc striking and carbon rotating mechanism.

One of the most recent developments in arc lighting is a concentrated arc comprising permanent electrodes enclosed in a bulb filled with an inert gas. A brilliant white light of about 65,000 candles per square inch is produced on a 0.003- to 0.100-inch spot on the refractory oxide-coated cathode which makes the lamp valuable as a projection device. The lamp operates on direct current in sizes from 2 to 100 watts, and a 1,500-watt size is contemplated. A special circuit is necessary to operate the lamp because it requires 1,000 volts for starting and 130 volts for burning.

Light sources brought to a glowing temperature of incandescence usually are accompanied by infrared or heat radiation and very little ultraviolet radiation. Generally speaking, incandescent sources provide continuous spectra. In variety, range of sizes, simplicity, readiness of application, and wide acceptability, incandescent lamps are of very great importance in electrical service. The relatively low American rates for electric energy and the relatively low prices for American lamps have made possible great strides in electric lighting practice since the introduction of the incandescent filament lamp by Edison in 1879.

INCANDESCENT FILAMENT LAMPS

Among incandescent filament lamps generally employed for illumination, the range of energy conversion is approximately 10–20 lumens per watt which represents a very low efficiency. Even for molten tungsten at 3,655 degrees Kelvin, the maximum radiation possible is approximately 50 lumens per watt. Maximum efficiency of solar radiation has been estimated at approximately 86 lumens per watt, corresponding to black body radiation at 6,500 degrees Kelvin. Tungsten probably will be used as the incandescent filament for some time because it approaches black body radiation better than other materials. By increasing the operating temperature of tungsten filaments 100 degrees Kelvin over the present operating temperature, which is 1,000 degrees less than molten tungsten, the luminous efficiency can be increased 2–2.4 per cent, but for such a step cost is increased about 600 per cent. Approximately 20 per cent of the output of the power industry is consumed in light production and even small gains in lamp efficiency are important. The average industrial load based on plant area is 2–4 volt-amperes per square foot for lighting and 8–10 volt-amperes per square foot for power. In line with power demands the light cost today for 50 foot-candles, which is considered good practice, is less than for 10 foot-candles in 1926, when the dollar adjustment is taken into account.

The advantages of the incandescent lamp include practically instantaneous starting (accompanied by a large short-time inrush of current), filament thermal lag to reduce cyclic flicker above 40 cycles per second, close approximation to unity power factor, ready substitution of different sizes, the agreeable color of the light, and a

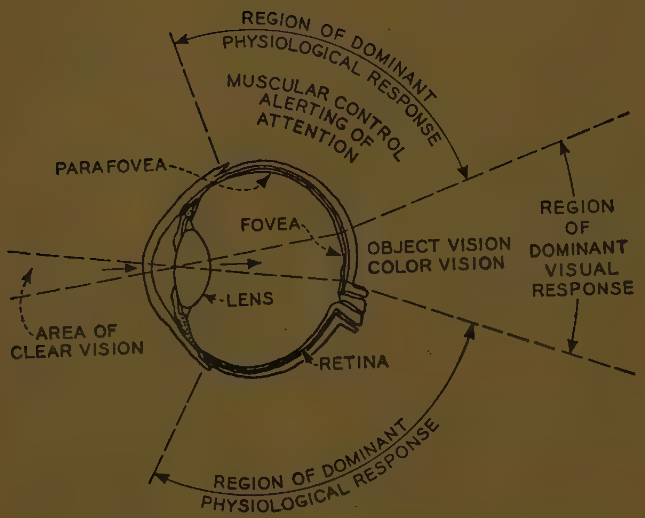

REGION OF DOMINANT PHYSIOLOGICAL RESPONSE
MUSCULAR CONTROL ALERTING OF ATTENTION
PARAFOVEA
FOVEA
OBJECT VISION
COLOR VISION
REGION OF DOMINANT VISUAL RESPONSE
LENS
AREA OF CLEAR VISION
RETINA
REGION OF DOMINANT PHYSIOLOGICAL RESPONSE

Figure 1. Diagram of human eye showing regions of dominant response

90 per cent lumen maintenance factor. Humans have evolved under sunlight and firelight and the two form extremes of radiation that approximate black body character. Incandescent electric lamps confront the human with a light color quality that is agreeable.

Unfavorable qualities of the incandescent lamp are sensitiveness to voltage variation (5 per cent decrease in voltage causes 15 per cent decrease in light output), too much heat, low efficiency, and bulb blackening from sublimation of tungsten causing reduction in lumen maintenance.

The most recent developments among incandescent illumination sources are: a new 2,500-lumen series street lamp of smaller physical size to permit smaller luminaires, and having a life of 2,000–3,000 hours; a 50,000-candle power, 500-watt photography spotlight; a semi-silvered 300–500-watt bowl lamp for indirect and accent lighting in commercial applications; sealed beam lamps up to 35 and 45 watts with a 12.5–16.7 per cent increase in lumen rating; and a bowl lamp rated at 200 watts, 115–125 volts, which is frosted and has the inside of the neck coated white to provide a type of lighting similar to the familiar Illuminating Engineering Society bulb and diffusing bowl combination.

VAPOR DISCHARGE LAMPS

However convenient, cheap, and simple incandescent lamps undoubtedly are, their ceiling of limited efficiency has spurred the scientist on to studies of other sources, notably the vapor discharge lamps, which include the fluorescent lamps. In the generation of light by passing an electric discharge through mercury vapor at low pressure (pressure of the order of about 0.003 millimeter of mercury), the radiation is emitted mainly in the ultraviolet range and only a very small amount in the infrared. The spectral energy curve of such a mercury vapor discharge shows that the radiation is no longer continuous but occurs as narrow spectral lines. A high proportion—some 50 per cent—of the input energy is emitted in mercury resonance radiation in the 2,537-angstrom adjacent wave band.

In order to raise the luminous efficiency of a mercury discharge, the strong 2,537-angstrom resonance radiation must be suppressed and the relative intensities of the other lines, especially the visible, must be raised. The success of our present-day mercury lamps has been brought about by doing this very thing.

The first commercially practical arc discharges through mercury vapor for the generation of light were made by Peter Cooper Hewitt in about 1901. He found that a discharge through a column of mercury vapor in a well-exhausted tube between pool electrodes has electrical properties very similar to that of an arc between solid carbons. The luminous efficiencies of these early arcs, about 25 lumens per watt, were considerably higher than was attainable with the best incandescent lamps of that time. However, the color of the light, because of absence of red, was objectionable for many uses. The efficiencies of these mercury arcs depended to a considerable extent upon the current through a given discharge, that is, upon the mercury vapor pressure. The lamps required direct current or its equivalent with a ballasting resistance to limit the current because of their negative volt-ampere characteristic.

Some 20 years later the operations of mercury arc discharges were improved and simplified greatly by the substitution of thermionically emitting cathodes for the mercury pool. By the further addition of an inert gas, such as argon, at a relatively low pressure—two to four millimeters or more—the ease of starting and the stability of the discharge were improved greatly at no sacrifice of efficiency. The amount of mercury required was reduced (to just a drop) and the new lamps were safer to handle by avoiding breakage from the hammer action of the mercury in the earlier evacuated tubes. Discharges can be maintained at lower mercury pressures than was possible without the inert gas and the lamps are readily adapted to operation on alternating current.

The mercury vapor discharge resonance radiation at 2,537 angstroms, which represents about 85 per cent of the total radiant energy in a low-pressure discharge, diminishes in relative importance as the mercury vapor pressure is raised, and that at the higher pressures an appreciable proportion of the radiation falls within the visible range. Spectrograms show the shift in the radiation toward the longer wave lengths as the mercury pressure in the discharge is raised. The result is that relatively more energy is generated in the visible and less in the ultraviolet. At pressures approximating one atmosphere and higher, a continuous background radiation fills the space between the lines and materially improves the color of the light and increases the efficiency from the mercury vapor arc-discharge.

The bacteria-killing lamp in special glass is an illustration of a low-pressure mercury discharge. The lamp operates at a temperature only a few degrees above ambient, and the special glass has a transmission for the 2,537-angstrom radiation practically as high as quartz, does not solarize appreciably over thousands of hours, and transmits a negligible amount of the shorter radiations which produce sometimes objectionable ozone. The 100-watt quartz arc commercially known as *A-H4* is a good example of a short high-pressure—about eight atmospheres—arc in quartz. To prevent cooling by air currents, this lamp is enclosed in an outer bulb. The lamp has an efficiency of 30 lumens per watt. The 400-watt *D-H1* quartz mercury arc is a somewhat similar lamp although with a longer arc stream and operating at a lower (about 2.5 atmospheres) pressure with an efficiency of 50 lumens per watt. The 1,000-watt *A-H12* quartz arc has an arc stream length of about five inches, and operates at a mercury pressure of about 1.5 atmospheres with an efficiency of 60 lumens per watt, while the 1,000-watt water-cooled quartz arc 1.5 (*A-H6*) operates at a pressure in excess of 100 atmospheres which is made possible by water cooling of the quartz. The efficiency of this lamp is about 65 lumens per watt. Colored objects illuminated only by the high pressure mercury arcs still show the absence of certain wave lengths.

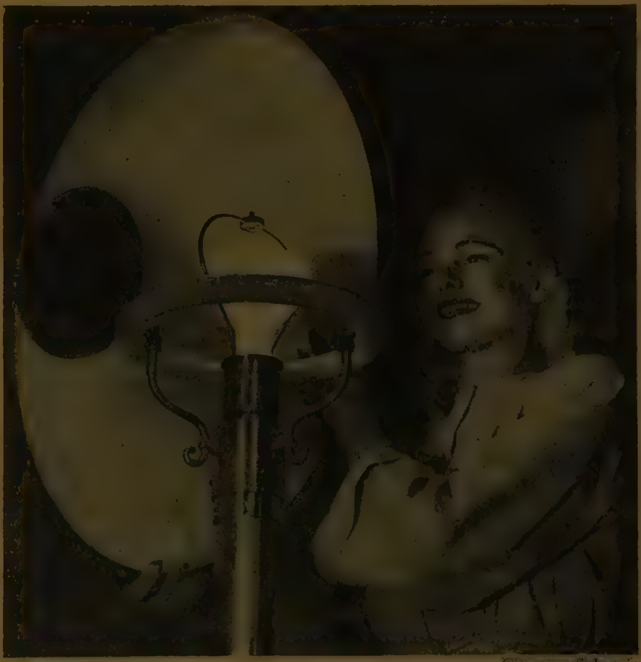
OTHER METAL VAPOR ARCS

By the substitution of cadmium or zinc for mercury, arcs in these metal vapors are obtained which operate as satisfactorily as mercury vapor discharges. The size and shape of the arc tubes—either quartz or glass—must be so chosen that the metal vapor generated by the discharge cannot condense in a part of the lamp where the temperature is too low for the evaporation of the metal. Cadmium and zinc arcs have strong spectral lines in the red, blue, and ultraviolet with no radiation in the orange and the yellow-green bands. The possibilities of combining one of these vapors with mercury to produce light similar to daylight has been suggested and applied with some degree of success. The vapor pressure of cadmium and zinc may be increased by operating the arcs at higher currents thus producing higher temperatures. Under these conditions the spectral lines are broadened as with mercury. With low-pressure cadmium a luminous efficiency of 3 to 4 lumens per watt is possible and up to 20 lumens per watt for high-pressure cadmium discharges in quartz. The luminous efficiencies of low-pressure zinc arcs is of the order of 2 to 3 lumens per watt and approaches 10 lumens per watt for high-pressure arcs. A similar arc discharge through sodium vapor in a bulb of very exacting design concentrates all the radiation at 5,893 angstroms (in the yellow region of the spectrum) no matter how the lamp is treated, with a possible efficiency of over 60 lumens per watt, but again with the serious lack of color range, and the sodium vapor attacks glass. A tellurium vapor discharge lamp is a curiosity because of the strong continuous spectrum superimposed on the weak characteristic tellurium line or band radiation.

From the discussions on high-pressure mercury, cadmium, and zinc arcs it is apparent that further improvements in luminous output are limited only by the temperatures at which the container melts, or softens, or reacts with the vapors in the discharges. If the magnesium oxide or aluminum oxides, which now are made experimentally in transparent glass-like form, can be produced in tubes and suitable electrodes can be found for these, even greater improvements in vapor discharges may become possible.

The use of a quartz arc tube permits the operation of the discharge at higher vapor temperatures and, consequently at higher pressures than is possible where a glass arc tube is used. This increases efficiency, gives a greater light output, develops a higher brilliance of the arc, and makes it possible to operate the lamp in any position. It also improves the color of the light. Since the introduction of thorium cathodes in mercury vapor lamps in 1941 to eliminate the destruction of the quartz arc tube due to corrosion of previously used barium electrodes, the use of an evacuated outer bulb, and bulbs of larger size have been the major improvements. This reduces the evolution of moisture and hydrogen gas from the glass thereby prolonging the life of the quartz tube.

In the incandescent lamp the spectral distribution is continuous and is controlled by the operating temperature. It is not possible to limit its output to any specific



Courtesy Sylvania

Figure 2. Bowl lamp provides both indirect and direct lighting without supplementary fixtures and circular fluorescent tube supplies low brightness source of illumination

portion of the spectrum except by means of filtering which wastes a great amount of radiation, but the gas discharge lamp may be controlled through variation of the gas composition or pressure, or by the fluorescent coating which converts the initial radiation. This may or may not be an advantage depending upon the application.

Distinct advantages of this lamp are its comparatively high efficiency, long life, and production of ultraviolet and vitamin *D*. The necessity for a starting circuit and ballast are not great disadvantages. Lumen maintenance in some recent mercury vapor lamps has been determined at about 80–85 per cent after 70 per cent of rated life has expired. This varies with hours per start and other factors, however. A disadvantage of these lamps is their liability to extinguishment or inability to start in environments where temperatures fall below 32 degrees Fahrenheit, unless special precautions are taken. Also, when operating on frequencies below 25 cycles per second, there is sufficient time lag to allow electrodes to cool and prevent restriking. Voltage drops of greater than 15 per cent also are causes of arc failure and restriking is not possible until there is a decrease in vapor pressure, which is dependent on cooling of the lamp.

Mercury vapor lamps for street lighting, which are just coming into the fore, provide a bluish-white light with a new high efficiency and effectiveness. The quartz mercury vapor lamp is the type expected to be in highest demand because of its small brilliant arc and freedom from restriction as to burning position. Improved lighting will do much to cut the toll of after dark accidents on highways. Two new 1,000-watt quartz mercury vapor lamps have been developed recently, both having the same lumen output and life. The lamps are rated at 60,000 lumens with life of 2,000 hours at five hours per start. One of the lamps has a special enclosure which permits operation in positions other than base down. A 3,000-watt mercury vapor lamp having a 120,000-lumen output and a life of 2,000 hours also has been produced. A 4-watt 2,537-angstrom bactericidal lamp has been designed for small applications. There was a 15-kw air cooled mercury vapor lamp reported developed in Germany during the war, but no material has been found on it.

Figure 3. Self-contained reflector sunlamp and high intensity mercury vapor lamps

FLUORESCENT LAMPS

The fluorescent lamp is the youngest and probably the most promising of light sources today. Development in the United States on fluorescent sources started only 12 years ago; before that time, fluorescence was a phenomenon generally observed only as faint glow to dark-adapted eyes, and its adaptability to the brilliance and light output required for commercial light sources seemed fantastic. First extensive use of fluorescent lamps was at the New York World's Fair in 1939–1940.

A fluorescent lamp is a light source in which all, or the major part of the visible radiation, is produced by a flourescent material, commonly called the phosphor. In all important commercial designs of today, this action is produced by passing an electric current through a mixture of mercury at about 10 microns pressure to produce ultraviolet, and a low pressure of starting gas, such as argon, neon, or a mixture. Various radiations excite fluorescence, but ultraviolet has been found the most efficient. With proper design, a large part of the input energy is converted to the ultraviolet resonance line of mercury at 2,537 angstroms. When this ultraviolet radiation strikes the thin layer of fluorescent material on the inside wall of the bulb, it is converted into light, of a color depending on the characteristics of the particular phosphor. Studies indicate that the output of fluorescent light is strictly proportional to the intensity of the ultraviolet radiation striking it, and that no significant saturation or fatigue effects occur. Since the fluorescent lamp is, basically, an electric discharge lamp, it possesses the need for a cathode and an anode, and for a ballast and circuit to initiate and stabilize the arc. Fluorescent lamps commonly have arc gaps many times their tube diameter, for reasons to be discussed.

Fluorescent lamps depart from the ideal spectral distribution (but not as much as filament or discharge sources), for they lack the ideal proportions both of blue and of red. The effect of the yellow-green mercury lines is to exalt the brilliance of corresponding yellow and green pigments to a degree that is not experienced in other light of equivalent synthetic ocular value, but red pigments generally appear dull. However, this lack of low-luminosity radiation results in a theoretical efficiency for this spectral energy distribution of 300 lumens per watt.

Fluorescent lamps are unique in their great range of possible colors at high efficiencies, greatly exceeding any possibilities of discharge or filament designs, because thousands of definitely different colors are obtainable by various mixtures of present standard fluorescent materials. Among the white and near-white colors now available are 3,500-degree Kelvin white, daylight (6,500-degree Kelvin white), the recently introduced 4,500-degree Kelvin white, soft white, and industrial white. In fact, any colors lying within the area formed by joining the color points of the various phosphors on the International Commission on Illumination color diagram can be obtained with an appropriate mixture of phosphors. None of these requires subtractive filters, and therefore is produced at high efficiency. The wide choice of colors is, to some extent, an embarrassment of riches, not only to maintain uniformity in colors already standardized, but also to limit the variety of additional standard colors, so that the advantages of mass production, low cost, and easy availability of replacements, may continue.

There are future possibilities in the improvement of present phosphors, and in the development of new ones. Approximate measurements indicate that present phosphors are transforming energy at about 80–90 per cent efficiency within the quantum limit outlined below; so, prospective gains there, amount to 10–25 per cent. New phosphors, however, may yield new colors or more desirable spectral energy distributions than present ones. Another field is the development of phosphors for fluorescent ultraviolet radiation, such as the *360-BL*, which produces efficient radiation in the 3,600-angstrom range (near-ultraviolet), and developmental erythemal phosphor, which produces efficient radiation in the skin reddening and tanning and vitamin *D* formation range, around 3,000 angstroms. Phosphors are *theoretically* possible which will radiate any spectral band of longer wave length than the exciting short-wave 2,537-angstrom radiation. So, any longer wave ultraviolet, visible, or infrared radiation is possible.

FLUORESCENT ENERGY LOSS

This leads to the discussion of an important cause of energy loss in the fluorescent lamp. According to a concept in physics first proposed about 40 years ago, and not contradicted basically since, a wave length transformation of energy, such as that in the fluorescent lamp from the exciting ultraviolet to the visible radiation, can occur only at a maximum limiting efficiency represented by the ratio of the wave lengths. This is known as the quantum rule. Because the ratio of wave lengths in fluorescent lamps is about 50 per cent, an energy loss of 50 per cent is involved and limiting efficiencies on green lamps, therefore, become about 265 lumens per watt, and, on 3,500-degree Kelvin white, about 150 lumens per watt.

Fluorescent lamp design and performance for maximum light output, definitely are tied to the maintenance of a bulb-wall temperature in the vicinity of 40–50 degrees centigrade, which is required to establish the vapor pressure of mercury to yield maximum efficiency. Any variable which affects bulb-wall temperature, therefore, affects light output and efficiency correspondingly. Overheating must be avoided by avoiding high-temperature applications, by spacing and ventilating lamps well in their fixtures, and by limiting them to a design wattage to produce this temperature. So, to maintain optimum efficiency, high-wattage fluorescent lamps must have proportionately high surface area. Temperatures below the optimum must be avoided by conserving lamp heat with jackets if they are subject to outdoor winter temperatures.

A further problem of low-ambient temperatures is that lamp starting becomes more difficult. In lamp starting using cathode preheat and a transient surge, this can be partly overcome by the use of a lower pressure of starting gas at some expense of life performance. Also thermal starters with series capacitors have been found better than the glow type below 50 degrees Fahrenheit.

Many other design variables, in addition to bulb-wall temperature, are involved in the current and wattage rating of fluorescent lamps. Low ratings yield relatively high initial efficiency, low brightness and glare, and reasonably satisfactory lumen maintenance, but have rather low lumen output. Operation at high ratings reverses the picture. High current densities also decrease efficiency because resonance radiation is produced less efficiently. Different sorts of lighting applications require the availability of both designs. One recent development of interest in this connection is rating lamps for a range of wattage.

Even at optimum bulb-wall temperature, conversion of input energy to the 2,537-angstrom mercury line is about 55 per cent in the most efficient lamp designs. Although this is a tremendously high efficiency for conversion to a single spectral line, and a major reason for the existence and success of the fluorescent lamp, it represents another severe cut in attainable efficiencies. Remaining discrepancies result from phosphor imperfection, coating absorptance, decline in output during the first 100 hours, which is the standardized rating point, and practical limitations in lamp manufacture.

What determines this 55 per cent figure, and to what extent is it capable of improvement? In hot-cathode

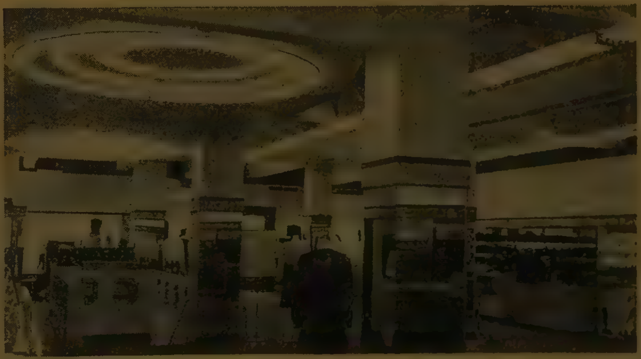


Figure 4. Cold-cathode installation showing application in both straight and circular configuration

designs, a fixed loss of 15–20 volts occurs at the electrodes. This is minimized by lamps of long arc-gap and high voltage, and reductions in end loss would not have much effect on efficiency. Cold-cathode designs have an electrode drop in the range 85–200 volts, depending on design. This relatively high value makes long length and high voltage essential for satisfactory efficiency. Their common lengths, therefore, are six feet or longer. In the positive column, which is the center section of the arc, the mechanism of production of 2,537-angstrom radiation is not quantitatively known. By experiment it is known that mercury vapor produces far higher lamp efficiency than any other gases or vapors tried to date. A disadvantage of metallic vapors other than mercury, is that they require an elevated temperature to furnish the desired vapor pressure. Consequently, as with the sodium lamp, they require considerable wattage just to maintain vaporizing temperatures, and so, to date, are not feasible.

The properties of the fluorescent coatings on the inside of the bulb wall are relatively well known and controlled. Coating thickness is a compromise between the need for a thick one to absorb and utilize all the impinging ultraviolet radiation, and the need for a thin one to minimize absorption of the generated light. The absorptance of present commercial coatings is 8–10 per cent. This may be capable of future improvement by obtaining whiter phosphors and by reducing darkening in lamp processing; again, though it represents a minor loss and therefore possiblity for gain in efficiency is small.

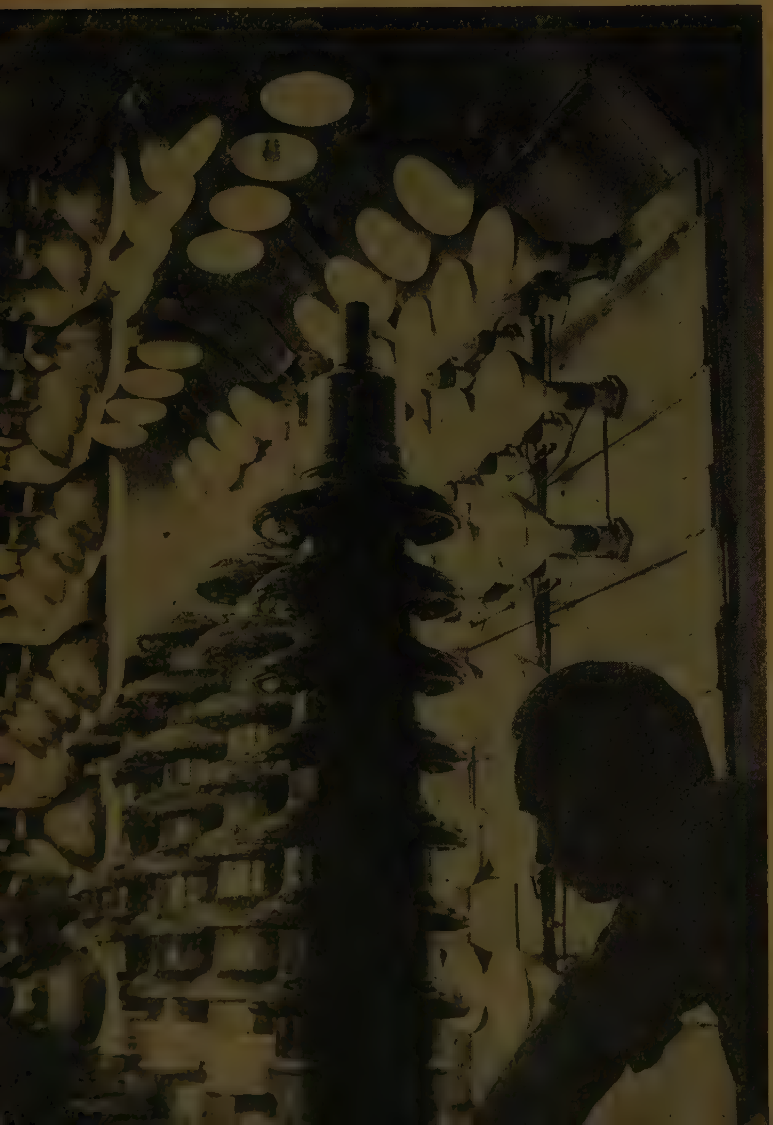


Figure 5. Infrared lamps heat capacitor bushings prior to their filling with hot insulating plastic to prevent cracking

Many internal reflections occur from the coating, and brightness is built up by interreflections. Therefore, relatively short lamps suffer in efficiency because a longer proportion of their total length is required to build up normal brightness.

Through lamp life, the coating steadily decreases in effectiveness, not through any fundamental change in efficiency of the phosphor, which usually can be restored to original brilliance by heating, but through some physical or chemical reaction of the mercury vapor and the coating. It is this lumen decline which limits the economic life of fluorescent lamps today. Lives to cathode failure of several thousand hours are common on hot-cathode types where starting is infrequent, and cathode life may be indefinite on cold-cathode types. But, with both alike, lumen output commonly drops 20 per cent or so from 100 to 1,750 hours, and roughly logarithmically thereafter. At present lamp prices and lower rates, replacement is indicated economically for a life of around 5,000 hours. The improvement of lumen maintenance is an outstanding problem of fluorescent lamp development today, and success will bring with it the prospect of longer useful life. No loss of lumen output occurs if the coating is excited by rare gases, but, as mentioned before, their efficiency is too low to be commercially useful.

LAMP STARTING

In the conventional hot-cathode lamp preheat-start circuit with starter, the inductive kick generated when starter contacts open is usually sufficient to break down the arc gap, regardless of ballast open-circuit voltage. So, open-circuit voltage is not determined by the value required to start the lamp. Rather, the voltage is determined by the value required to *sustain* the arc, under conditions of minimum line voltage and maximum lamp voltage, and to hold the starter out of action, once the lamp has started. These needs commonly result in an open-circuit voltage of about twice lamp voltage, and in an uncorrected circuit power factor of about 50 per cent. This ratio also produces satisfactory regulation of lamp characteristics for an assumed maximum line-voltage fluctuation of plus or minus 10 per cent from the 118-volt nominal rating point. If better regulation of line voltage could be assumed, a lower ratio could be used, with less ballast loss and better power factor. However, any large change in ratio would rule out the use of the glow-switch type of starter, which requires the existing voltage ratio for reliable action, and the substitution of more expensive kinds with additional limitations would be necessary.

Development trend is strongly toward instant-start designs of cathodes and ballasts, to eliminate the starting delay and operating complications of starting switches. To date, the standard method for instant-starting is the application at the lamp terminals of a high enough voltage to break down the gap. Many other schemes have been proposed, or are under development, but this is still the only standard one. Considerable investigation was carried out to keep this voltage at a minimum, leading to the adoption of a starting stripe on the lamp. It has been found that the required ratio of instant-starting to operating volts shifts with lamp dimensions. For short, fat lamps, it is quite high, and a bulky, expensive, high-loss ballast is required Also, the high ratio results in a low power factor circuit. For long, slim lamps the ratio approaches two to one, which hot-starting circuits require, and the penalty for use of instant-start circuits is thereby reduced.

In either type of circuit, 2-lamp ballasts are heavily predominant, constituting one lag and one lead circuit, so that input power factor to the circuit is always in the range 95–100 per cent, resulting in customer and power-supplier advantages. The problems to the lamp and ballast manufacturer of the lead circuit, however, have been numerous, and not all are fully solved yet. Lamp current wave shape affects lamp performance and manufacturer's specifications, therefore, commonly set a peak-rms ratio of 1.7 as permissible maximum to obtain rated lamp performance.

FLUORESCENT CIRCUIT POWER SUPPLIES

The limitations and possibilities of various circuit supplies can be dealt with briefly. Operation on direct current eliminates cyclic flicker, but has the outweighing disadvantages of resistance ballast loss, yet still requiring an inductance to furnish a transient for reliable starting, and the need in longer lamps for a polarity-reversing switch to avoid the concentration of the positively-charged mercury ions at the negative end, thus leaving the positive end of the lamp without mercury vapor, and therefore without fluorescent light. Also the lamp is sensitive to voltage changes on direct current. Severe cyclic flicker and bulky ballasts make 25-cycle supply unsatisfactory. Of course, the standard for development and comparison is 60-cycle supply. Cyclic flicker is not generally bothersome, and is cut approximately in half with the mixed light from a two-lamp hot-start ballast or from lamps connected to the different phases of a polyphase power supply. Tests at 400 cycles indicate that ballast size is cut approximately in half, lamp efficiency is increased about 20 per cent by the elimination of about seven or eight volts of the fixed drop, and capacitors can be used rather freely, in small capacitances, as starting aids and ballasts because lamp voltage wave shape has become sinusoidal, and capacitors do not unload through the lamp as they do at 60 cycles on the ignition peak. Higher radio and power frequencies are offering interesting fields for determination of variations in lamp performance. The losses involved in conversion and transmission on these frequencies make them unpromising for general use.

A drawback to the hot-cathode fluorescent lamp is necessity for starter and ballast. Because the starting current is about double the operating current, the ballast of the lamp becomes overheated if a deactivated lamp is left in the circuit, unless a special starter is used. An extinguished lamp seems a more acceptable signal for replacement than does a blinking lamp which is very annoying and distracting as well as hard on the ballast. Dimming of lamps in series remains a problem although one manufacturer has developed a special transformer for the purpose.

Humming noises from auxiliaries and radio interference are aspects that must be guarded against, especially in home lighting service. Radio interference arises from feedback through wires of the house circuit, radiation of the high-frequency current components from the wires, and radiation coming directly from the lamp. It is indicated that the average circular lamp without benefit of filter or shielding must be at least seven feet from the antenna. Noise generation may have a wide variation at each fresh lamp start, but it has been found that bulb radiation noise can be eliminated by placing an adequate grounded screen between lamp and antenna at separations of no more than six inches.

Because fluorescent lamps are not concentrated sources of light, they have low brightness and consequently produce very little glare. Soft shadows result from their radiation and heat dissipation is low and even. The quality of the light is of excellent value psychologically, and the variation of light output is only 1–2$^1/_2$ per cent for a one per cent voltage variation. Efficiency of fluorescent lights is a great advantage and because of this factor their use has been expanded considerably in England as a fuel conservation measure.

What of the future possibilities in lamp size and wattage? There appears no possibility of lamps of a size and wattage comparable with filament lamps. As has been pointed out, short-gap lamps have high end-loss, and efficiency is low. Lamps must be long to be efficient, and the average length is likely to increase. Long deliberation at one laboratory has produced the following rule on maximum lamp length: "No lamp shall be longer than the maximum dimension of the room it is intended to fit!" Increasing diameter as a means of increasing wattage rating has been tried, and such procedure permits maintenance of the desired bulb-wall temperature. However, it decreases lamp voltage and therefore increases the percentage of end-loss unless the lamp is made longer simultaneously. Lamps of long length and large diameter are theoretical possibilities for high efficiency, but are not attractive manufacturing propositions. Perhaps the strongest current trend is to provide long arc gaps without large over-all dimensions by physical configuration of the tube. Circles, grids, U-tubes, spirals, helices, and other shapes are suggested easily, but their reduction to mass production, low cost, and easy handling present real development problems.

A recent development in hot-cathode lamp operation is the use of a 150-watt 105-volt incandescent lamp for ballast in series with two 100-watt fluorescent lamps. The incandescent lamp operates at full efficiency with the fluorescents operating at slightly lower than normal efficiency. The cost of such an arrangement is lower than for an inductive ballast.

The 500 new subway cars soon to be put in operation by the New York City (N. Y.) Board of Transportation will be lighted by means of cold-cathode lamps. The cars will have 18 and 24 72-inch lamps operating on 600 volts of direct current. Cold-cathode lamps were selected because their life is independent of number of starts and they are instant starting. This is important because the number of third rail gaps at section breaks and crossovers is very high in the subway system. The relatively high voltages for starting and operation formerly were frowned upon for indoor use of cold-cathode lamps. However, subject to precautionary restrictions in the National Electrical Code, they are finding extensive use in industrial and commercial lighting service. Light emissions are available from 50 to 450 lumens per foot, and at least 10,000 hours of useful life is claimed for these tubes. The cold-cathode lamps are the outgrowth of sign equipment employing small diameter tubes filled with neon, mercury, helium, and argon to produce different colors for display purposes.

FLASH LAMPS

Another source of artificial light is worth mention here. Flash lamps, particularly the capacitor discharge type, are finding a wider range of application. A stroboscopic flash beacon has been developed which produces 30 million candle power for about one microsecond or about 25,000 candle power-seconds, with a power consumption of 200 watts. The Navy developed beacons for marine buoys with a flash length approaching one tenth of a second for better visibility. This same type of lamp is being used by some utilities and other organizations for safety warning in place of the old kerosene lanterns. Some work has been done in adopting flash illumination to television and motion picture photography with flash rates up to 96 per second. Stroboflash illumination was used extensively during the war for photography and emergency signals.

Dynamic Braking of D-C Motors

JOHN D. LEITCH
MEMBER AIEE

Automatic dynamic braking in event of power failure for two d-c series motors can be accomplished in several ways. The method will be determined by service requirements.

TWO identical d-c series motors frequently are used on a single drive because two smaller motors are more economical in cost and space and have a lower WR^2 than one larger motor. The two motors may be connected permanently in series, in which case a single controller is obviously adequate, or they may be connected permanently in parallel, requiring a duplex controller having separate reversing and accelerating contactors and separate resistors. Often double-pole contactors are used to insure simultaneous switching in the paralleled motor circuits.

It is desirable in certain important drives to provide automatic stopping in the event of power failure. This may be accomplished without magnetic brakes by using dynamic braking to decelerate the drive and inherent friction in the machine to bring it to rest.

DYNAMIC BRAKING IN ONE DIRECTION

Dynamic braking in only one direction requires a single pair of spring-closing contactors when the two motors are connected permanently in series as shown in Figure 1. The spring-closing contactors *FB1* and *FB2* close their contacts on power failure while all other contactors open. If motion is in the forward direction, a dynamic braking current will flow from *A1* at *1* through

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Essential substance of paper 47-133, "Dynamic Braking of Two D-C Series Motors," presented at the AIEE summer general meeting, Montreal, Quebec, Canada, June 9–13, 1947, and scheduled for publication in AIEE *TRANSACTIONS*, volume 66, 1947.

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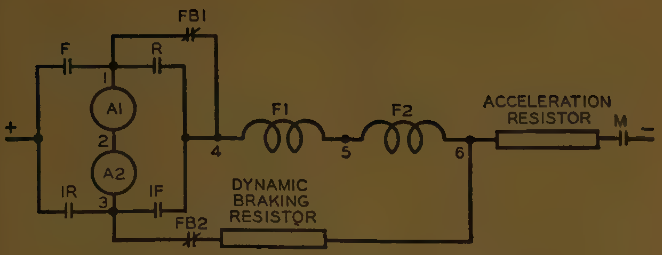


Figure 1. Dynamic braking in one direction

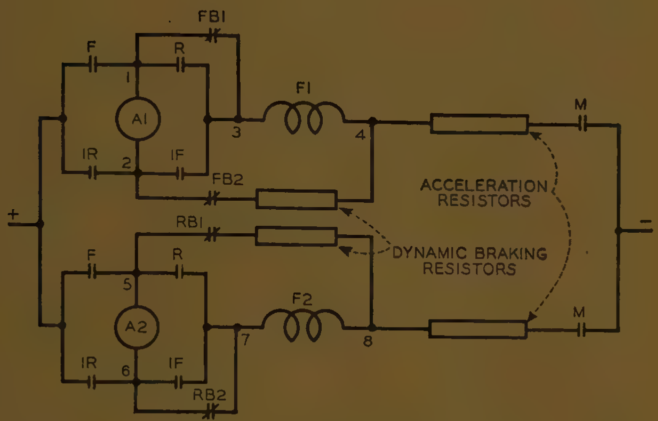


Figure 2. Forward braking with one motor and reverse braking with the other for parallel connection of motors

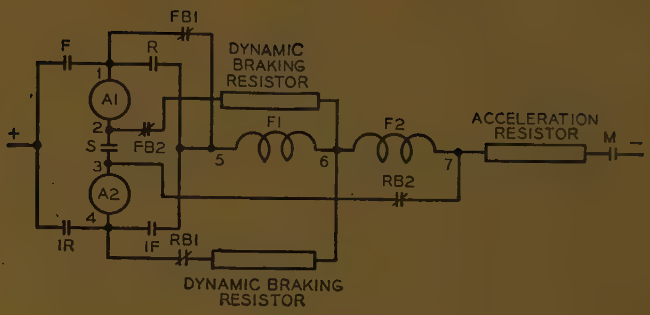


Figure 3. Forward braking with one motor and reverse braking with the other for series connection of motors

both fields without reversal back to armature *A2* at *3*. Thus the current reverses in the armatures only, a sufficient condition for dynamic braking. In the reverse direction, dynamic braking is not provided by the circuit of Figure 1 because the current is reversed in both the fields and armatures. Obviously, if the two motors are connected in parallel, the circuit of Figure 1 would be duplicated with only one motor in each part.

DYNAMIC BRAKING IN BOTH DIRECTIONS

Single-Motor Methods. A simple method of obtaining dynamic braking in both directions on a 2-motor drive is that which provides dynamic braking by one motor in the forward direction and by the other in the reverse direction as shown in Figure 2 for two motors in parallel. On many machines adequate braking torque can be provided in this way with considerable saving in control equipment.

If the two motors are connected in series, it is necessary to use an additional contactor *S* to separate the two armatures during dynamic braking as shown in Figure 3.

Sometimes with 2-motor drives it is desirable, in emergency, to operate the machine with one motor and still obtain dynamic braking in both directions in the event of power failure. If, in addition, the motors must be connected in series during starting, and later in parallel to obtain higher speeds, dynamic braking must be provided regardless of whether the motors are in series or parallel at the instant of power failure. The power circuit of a controller meeting these specifications is shown in Figure 4.

Each motor has associated with it four spring-closing contactors *FB1*, *FB2*, *RB1* and *RB2*. Should power fail while the motors are rotating in the forward direction, only the *FB* pair closes its contacts while in the reverse direction only the *RB* pair closes. This is accomplished by polarizing the spring-closing contactors.

Series and parallel operation is obtained by the series contactor *S* and the two parallel contactors *P1* and *P2* in the usual manner. Two 3-pole double-throw knife-switches *K1* and *K2* permit disconnecting either motor from the system. With both knife-switches in the up position, normal operation with two motors is obtained. With either of the two switches in the down position, the corresponding motor is disconnected.

If the two motors are connected in parallel only, it is possible to reduce the number of spring-closing contactors from eight to four by tying corresponding points on the two motors through bridging resistors. Another advantage of this circuit is that it permits disconnecting either motor from the drive while still providing dynamic

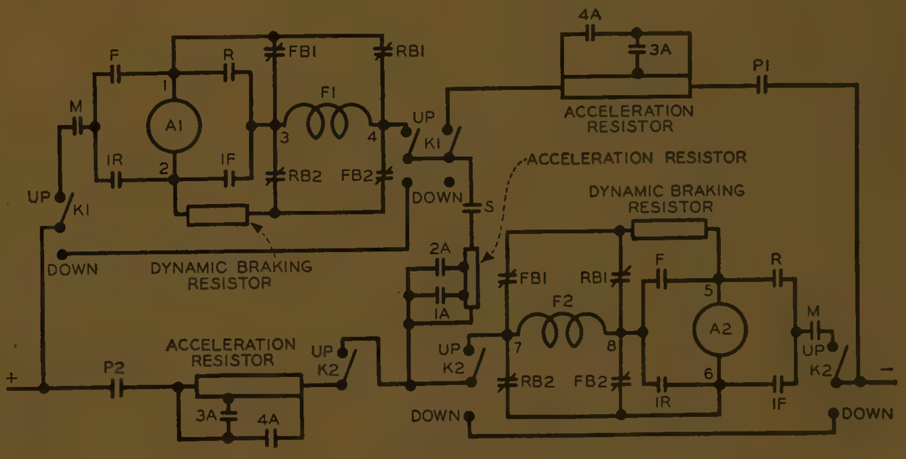
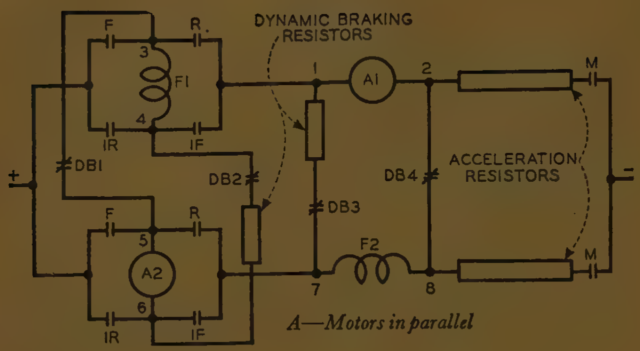
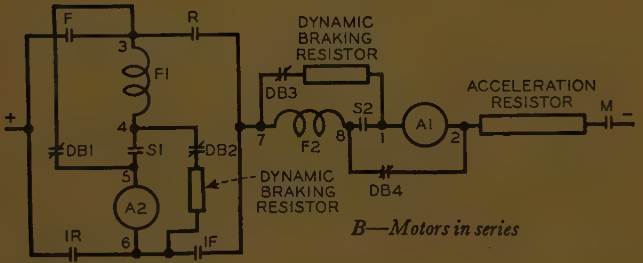


Figure 4. Braking in both directions. Single motor method



A—*Motors in parallel*



B—*Motors in series*

Figure 5. Reversal by reversing one armature and one field

braking in both directions with the remaining motor. This method also requires some means of assuring the closure of the appropriate pair of spring-closing contactors *FB* or *RB* according to the direction of motion at the instant of power failure.

There was some question as to the practicality of using bridging resistors because excessive circulating currents might be produced by any unbalance in the circuits and by small differences in the characteristics of the two motors. However, on test with two *MD408* motors, the bridging resistors could be reduced in ohmic value beyond that required for any practical application without producing circulating currents greater than ten per cent of full load current and then only during acceleration and plugging.

Two-Motor Methods. So far, methods applicable to a single motor have been applied to 2-motor drives. There are, however, a variety of 2-motor circuits which are applicable only to drives where the number of motors is a multiple of two. The main advantage of these circuits is that they require only four spring-closing contactors all of which are permitted to close their contacts on power failure. This eliminates the need for control equipment which will hold one pair of spring-closing contactors open according to the direction of motion of the motors at the instant power fails. The 2-motor circuits however have the disadvantage that the drive cannot be driven in emergency by only one motor without loss of the dynamic braking feature.

Reversal by Reversing One Armature and One Field. This circuit differs from all other circuits considered in this paper in that reversal is obtained by reversing the field of one motor and the armature of the other as shown in Figure 5. On power failure all four spring-closing contactors *DB1*, *DB2*, *DB3*, and *DB4* close their contacts to complete two separate dynamic braking loop circuits, in each of which the armature of one motor is connected in series with the field of the other. The direction of the dynamic braking currents in both loops is such that the fields are energized in their original direction while the armature currents are reversed. This occurs for both directions of motor rotation provided the motors are not being plugged when power fails.

Railway Method. A well-known method of obtaining dynamic braking in both directions on 2-motor drives has been used for some years on d-c electric railway systems, particularly on streetcars. Because of the infrequent reversal of traction motors, it is customary to use double-throw knife-switches in reversing the fields. The problem of plugging or rapid reversal is not a factor in the design of streetcar controllers. Traction drives are usually accelerated by first connecting the motors in series and later in parallel. It is also desirable to provide numerous steps of "service" dynamic braking so that the motors can be decelerated at a controlled rate. A typical circuit providing these features is shown in Figure 6.

A 4-pole double-throw knife-switch is shown for reversal of the fields. In accelerating, contactors *M1*, *M2*, *PS*, and *S* are closed, connecting the two motors in series. After acceleration has proceeded to a certain point, *S* opens and *P1* and *P2* close to connect the motors in parallel. On returning the control switch to the off point or coasting position, contactors *P1* and *P2* close or remain closed with the dynamic braking contactor *DB*. Contactors *M*, *M1*, and the accelerators drop out.

Modifications of the Railway Method. Where frequent plugging and reversing operations are necessary, the use of reversing contactors is indicated. These reversers may be used to reverse either the fields or the armatures with the same result. Figure 7*A* illustrates a modification of the railway method for two motors connected in

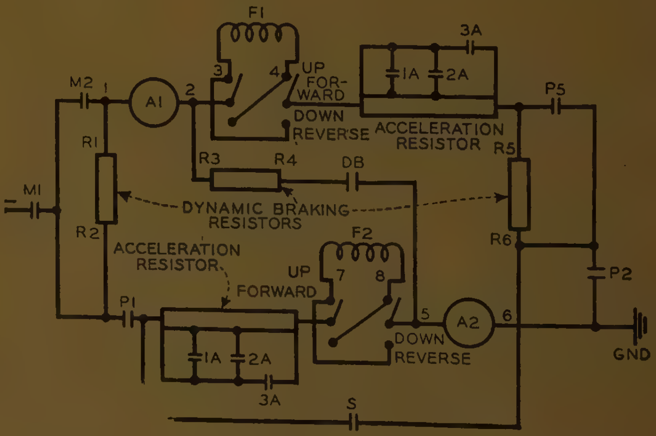


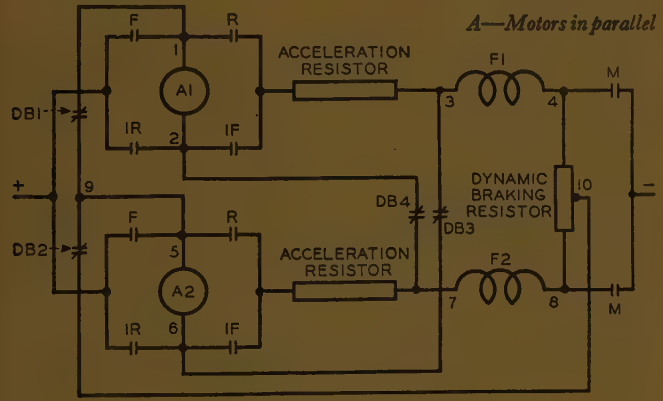
Figure 6. Railway method for series-parallel connection

parallel. Figure 7*B* shows the corresponding series connection. Four spring-closing contactors are essential in obtaining dynamic braking in both directions. The effect of shunting the field *F2* in Figure 7*B* with the dynamic braking resistors is negligible.

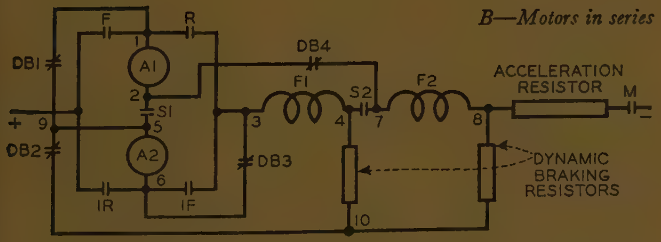
Assume the motors of Figure 7*A* to be running in the reverse direction with contactors *R*, *1R*, and *M* closed at the instant of power failure; these contactors will open simultaneously with the closure of the four spring-closers *DB1*, *DB2*, *DB3*, and *DB4*. The counter electromotive forces will be in the directions *1–2* in armature *A1* and *5–6* in *A2*. Dynamic braking current will flow from *2* at *A1* through field *F2* in direction *7–8* and back to *1* and *A1* through the common return conductor *9–10*. Similarly a current will flow from *6* at *A2* through field *F1* back to *5* at *A2*. The field currents are thus maintained while the armature currents are reversed giving dynamic braking. The dynamic braking current in the common conductor is the sum of the currents in the two armatures.

If the motors are rotating in the forward direction with contactors *F*, *1F*, and *M* closed, the counter electromotive forces will be in directions *2–1* in *A1* and *6–5* in *A2*. On power failure these counter electromotive forces would tend to reverse the currents in both fields simultaneously. Should it happen that the fluxes in both fields reach a zero value at exactly the same instant there is a possibility of losing the fields, permitting the motors to coast to rest without dynamic braking. On repeated tests with two *MD408* motors no such failure occurred.

The behavior of the circuit of Figure 7*B* is essentially the same as that of Figure 7*A*, the only important difference being the addition of two normally open contactors *S1* and *S2* for separation of the fields and armatures during dynamic braking.

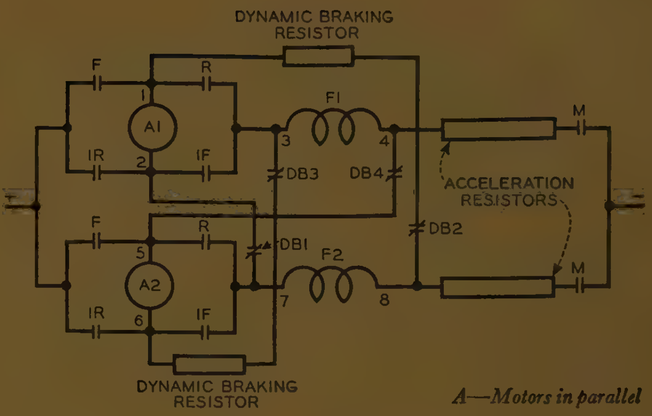


A—Motors in parallel

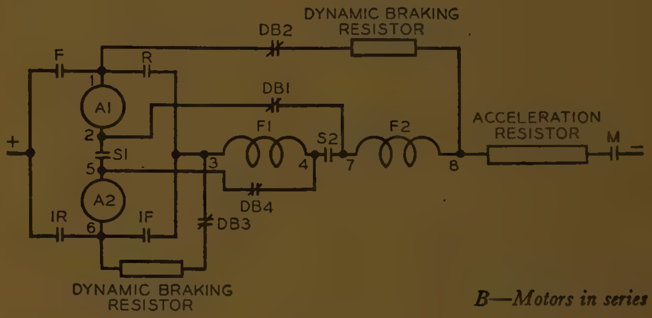


B—Motors in series

Figure 7. Modified railway method using common conductor



A—Motors in parallel



B—Motors in series

Figure 8. Modified railway method without common conductor

Further modifications of the railway method are shown on Figure 8. Comparison of these circuits with those of Figure 7 shows that the common tie between the fields and the common return conductor have been eliminated. The armatures are entirely isolated from each other during dynamic braking. In the reverse direction dynamic braking is provided without field reversal, while in the forward direction one motor must dominate to reverse the field of the other quickly as in the case of the circuits of Figure 7.

All of the circuits described in this paper were tested using two *MD408* series mill motors. The circuits behaved as analyzed and in no case did any of them fail to provide dynamic braking on power failure while running in either direction, while being plugged, while drifting or while drifting after plugging. It is simple to introduce slight dissimilarity in the characteristics of the two motors by shunting the field of one of them with a resistor.

While no experimental evidence indicated the need for a teaser field connection during drifting, it is felt that in all circuits except that of Figure 6, such connection should be added as a means of assuring an appreciable counter electromotive force across each armature during drifting or coasting with the control switch on the off point.

Graduated service braking is easily provided by additional contactors for short-circuiting portions of the dynamic braking resistors as the motor decelerates.

Insulation Resistance Measurements

E. W. GREENFIELD
MEMBER AIEE

The simplification stated by Ohm's law—resistance is the ratio of potential to current—is qualified for insulation materials. The current quantity is shown to be a superposition of four more or less independent components, each with different characteristics. This approach produces a method for eliminating common errors and inaccuracies from insulation resistance measurements.

PERHAPS the first of all electrical measurements applied to insulating materials was the determination of the resistance of such materials to current flow. Almost from the time the electroscope, the galvanometer, the ammeter, and the voltmeter became available, scientists applied these instruments to determine the relative abilities of conductors and insulators to hold their charges or to permit passage of electric currents.

The telegraph lines of 100 years ago were rated for efficiency chiefly by their d-c insulation resistance between conductors and to ground. Indeed this was a most important characteristic, considering the crude nature of the apparatus and insulating materials then procurable. With so much historical precedent, it is understandable that the measurement of insulation resistance, as an apparent necessity, has crept into specifications and standards for every type of insulating material now known.

Unfortunately, this oldest and supposedly simplest of dielectric measurements presents probably the greatest complexity, both in the doing and the interpretation.

INSULATION CURRENT—A COMPLEX PHENOMENA

When a steady source of potential is applied to a capacitor or cable, the current which flows in the circuit varies in rather a complex way with time. The current itself is made up of several components, each of which may be regarded as contributed by some special property of the capacitor (size, type, and condition of dielectric material) and the connecting circuit. These components and their numerous peculiarities may be tabulated as shown in Table I, and in Figure 1 they are shown graphically.*

The total current is made up of four components as follows:

1. Normal charging current.
2. Reversible absorption current.
3. Irreversible absorption current.
4. Leakage conduction current.

Following the outline given in the table, this total current will fall after application of potential from an instantaneous high value at a decaying rate to a constant lower value. The whole shape of the current-versus-time curve is influenced by the type of dielectric material present in the capacitor, the voltage, the temperature, and the external circuit resistance.

DEFINING INSULATION RESISTANCE

By Ohm's law, resistance is defined as the ratio of potential to current. This definition is *general* and applies equally to insulating materials and to conducting materials. By definition, then, the insulation resistance of a capacitor is equivalent to the applied potential divided by the current which flows in the circuit. It has been shown that the current which flows is not constant with time but rather is a complex function of many variables. What current then should be taken which together with the applied potential will yield insulation resistance?

This is a question which has puzzled dielectricians and confused the science every since the discovery of dielectric absorption in 1865 by Siemens.[2]

"FINAL" CURRENT AS A BASIS

If a steady potential is continued long enough, so that both the normal charging current and the absorption currents decay to zero, there will remain the constant leakage conduction current. It might seem logical to use this so-called final current as a measure of the insulation resistance. But a major disadvantage of using it is the length of time required to reach this stage of the current–time curve. For impregnated paper, the "final" current is not reached for 40 minutes or more; for high-grade rubber insulation, the time is even longer.

A more serious disadvantage, however, is that the resistance so computed is much higher than the resistance offered by the insulation for currents applied for shorter time intervals. For example, during switching operations on d-c circuits, the initial insulation resistance is much lower than after steady-state conditions

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Full text of a paper presented at the conference on cables held April 23, 1947, during the AIEE North Eastern District meeting, Worcester, Mass.

E. W. Greenfield is head of the electrical laboratory, Anaconda Wire and Cable Company, Hastings-on-Hudson, N. Y.

* The absorption components are shown as departing from simple power functions; this is usually the case for impregnated paper.

are reached. More important still is the fact that, for a-c applications the "final" current, high insulation resistance, never is attained, as the dielectric continuously is being charged and discharged over very short intervals of time.

ONE-MINUTE INSULATION RESISTANCE

Thus, the industry has been forced to effect a compromise in the measurement of insulation resistance. By convention since 1895 in the power cable applications (before that in the communication industry), the current has been measured after *1-minute* electrification, and this value used to compute a so-called 1-minute insulation resistance of the dielectric—nothing more or less.

Insulation resistance measured after 1-minute electrification has the following disadvantages:

1. Difficult to measure accurately, as at 1-minute elapsed time the current still may be changing rapidly for most solid dielectrics.
2. Bears little relation to the insulation resistance of the material over some other time interval (60 cycles per second alternating current, for example, which has a time interval of only 1/120 second.)
3. Cannot be used as a criterion of quality between various insulating materials, as the magnitude and shape of every current-versus-time curve is different.

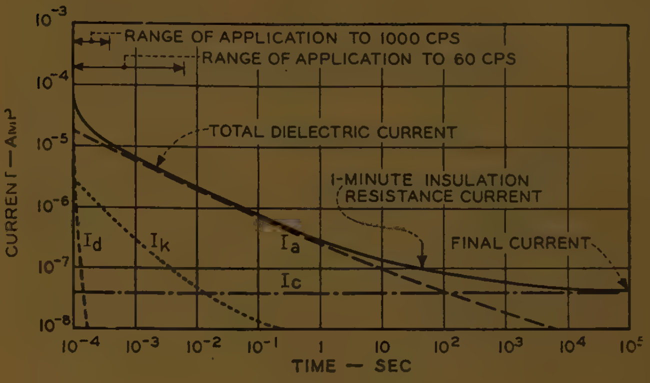


Figure 1

I_d = charging current

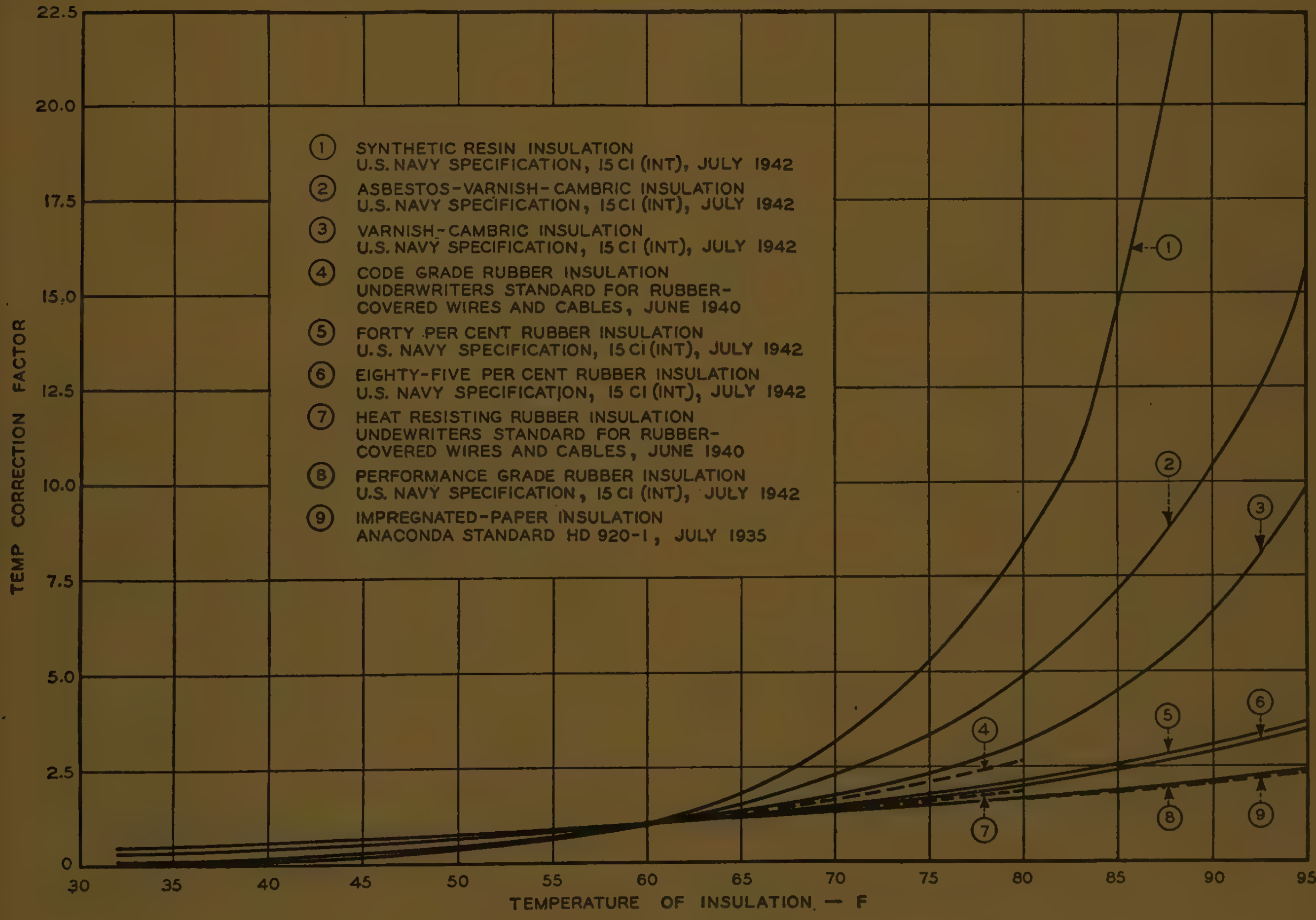
I_a = reversible absorption current

I_k = irreversible absorption current

I_c = leakage conduction current

Further complications arise in measuring insulation resistance. As the current persists over an appreciable time interval after any voltage application, the capacitor or cable being measured must be discharged completely before consistent insulation resistance measurements can be made; otherwise the current-versus-time curve obtained is influenced by the previous charging. The better the insulation, the greater the precautions necessary. Thus, for multiconductor cables, the test may take an

Figure 2. Temperature correction factors for various types of insulation



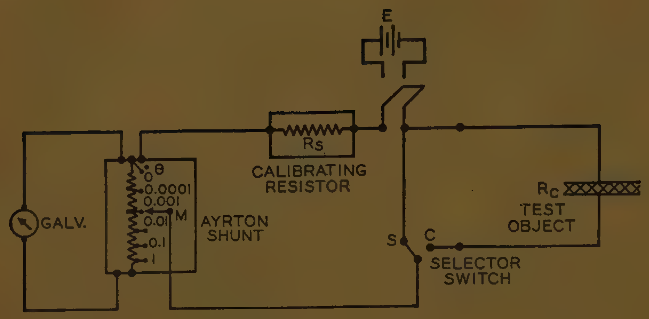


Figure 3a. Typical deflection-type insulation resistance set (no guarding shown)

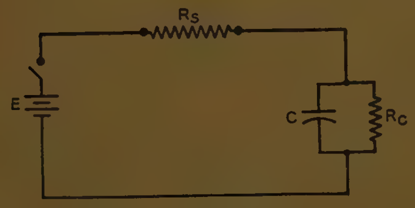


Figure 3b. Equivalent charging circuit

impractical length of time. Another important factor is surface leakage. This may be eliminated by suitable guard circuits, but more often is neglected in commercial measurements.

Finally, most insulating materials show large variation in 1-minute insulation resistance values with temperature. The variations are so steep that an error of a few degrees in temperature determination may cause a 25 to 50 per cent error in insulation resistance. Figure 2 shows temperature correction factors for various insulating materials at present accepted as industry standards.

The writer does not propose abandonment of the 1-minute insulation resistance measurement at this time. Taking cognizance of the almost universal usage of 1-minute insulation resistance, the writer rather would make clear the complexity of this test and, in particular, indicate how one source of error, namely charging current, may become appreciable under certain conditions and how, when necessary, this can be taken into account or eliminated. The question of charging current error in insulation resistance testing keeps cropping up where high capacitance objects or long cables are being measured to rigid specifications limits.

ERRORS DUE TO CHARGING CURRENT

Of the four components of the total dielectric current shown in Figure 1, the first, which arises from the normal polarization of the medium, termed normal charging current, is of a different character from the others. It is practically independent of the conductivity or resistivity of the insulation, being dependent only upon its capacitance and the resistance in the external circuit. A capacitor or cable having perfect vacuum as a dielectric (infinite resistivity) still must exhibit a normal charging current with a magnitude and variation with time depending upon the previously stated parameters. Hence, insulation resistance, as it is intended to be some sort of measure of the dielectric's ability to resist loss-producing current flow, must be computed from a current in which the normal charging component is completely absent or reduced to a negligible value. Succinctly stated this means: Insulation resistance is desired because it indicates something about service performance with alternating current or direct current, or is a criterion of material quality. It, therefore, should be based only on effective conduction currents and not on polarization or displacement currents.

Fortunately, in the measurement of 1-minute insulation resistance of most capacitors and cables, the time constant of the measuring circuit is sufficiently small so that normal charging current is reduced almost to zero long before the actual reading is made. Such is the case of the dielectric shown by Figure 1. However, where large capacitors are being measured, or materials of very high dielectric constant or a number of conductors in a multiconductor cable are grouped together, or a number of cables connected in parallel, or a very long cable or transmission line is measured, the charging current error may not be negligible. The following treatment indicates for these cases, how the charging current errors may be computed approximately and taken into account in the determination of insulation resistance.

Figure 3*a* is a circuit diagram of a typical and much used insulation resistance measuring device that employs a deflection method, in which the deflection of a sensitive galvanometer is compared first with a known standard or calibrating resistance and then with the unknown cable or capacitor connected into the circuit. With this method it is unnecessary to know either the current characteristics of the galvanometer or the battery potential. The Ayrton shunt serves to keep the dynamic characteristics of the galvanometer constant over a wide range of current requirements.

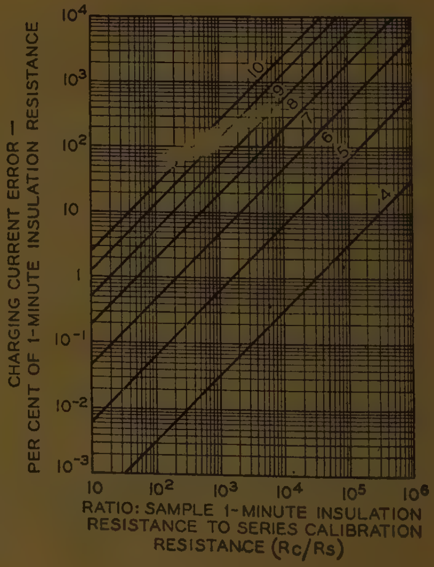


Figure 4. Error in measured 1-minute insulation resistance due to charging current as a function of series calibrating resistance, sample capacitance, and insulation resistance

Time constant (R_sC)

The usual equation for insulation resistance with this equipment is as follows:

$$R_c=\left(\frac{\theta_s M_s}{\theta_c M_c}-1\right)R_s \qquad (1)$$

where

θ_s and M_s = 1-minute galvanometer deflection and Ayrton shunt multiplying factor with standard resistor only in circuit

θ_c and M_c = 1-minute galvanometer deflection and Ayrton shunt multiplying factor with cable added in circuit

R_s = standard calibrating resistance

R_c = insulation resistance (1 minute) of cable

At the instant of closing the battery switch with the cable or capacitor in circuit, there is a rush of charging current into the test sample limited chiefly by the external circuit resistance. As the multiplying factor dial of the Ayrton shunt would be set on zero during this time, the entire external circuit resistance is practically equal to the calibrating standard, R_s. Figure 3*b* shows the charging circuit.

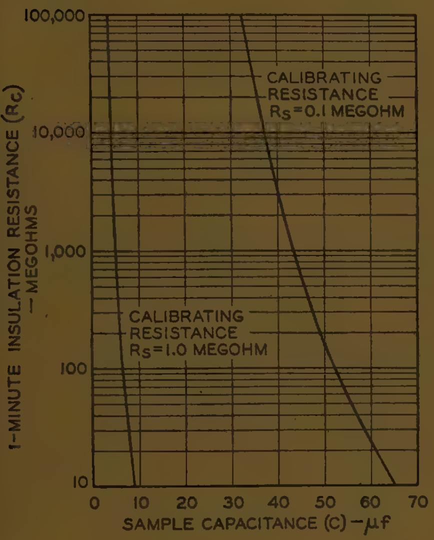


Figure 5. Relation of capacitance to 1-minute insulation resistance for a charging current error of 1 per cent

Two values of standard calibrating resistance shown

$$C=\frac{26}{R_s\left[\log\left(\frac{R_c}{R_s}\right)+2\right]}$$

The equivalent shunt resistance (representing the true "lossy" components) of the cable, R_c, has little effect on this charging current component (capacitance acts as a zero resistance at the instant of start of the charging) and, hence, does not influence its magnitude or variation. As time goes on after circuit closure, the charging current decays exponentially, following the well-known form (refer to Figure 3*b* for the simplified charging circuit):

$$I_{ch}=E\left(\frac{R_c}{R_s(R_c+R_s)}e^{-\frac{R_C+RT_S}{R_CR_SC}}\right) \qquad (2)$$

As for insulating materials, $R_c>>>R_s$, equation 2 simplifies to

$$\text{Charging current } I_{ch}=I_0e^{-\frac{T}{R_SC}}=\frac{E}{R_s}e^{-\frac{T}{R_SC}} \qquad (2a)$$

The other three current components (due to absorption, conduction, and so forth) are also present, each varying in its own particular manner, with time.

Hence, the total current at any instant of time, T, is

$$I_T=\frac{E}{R_s}e^{-\frac{T}{R_SC}}+\frac{E}{R_c+R_s} \qquad (3)$$

We derive the expression for R_c from the galvanometer readings on calibrating standard and cable as follows:

I_s, current on calibrating resistance only $=\frac{E}{R_s}=kM_s\theta_s$

I_T, total current with cable added in circuit $=\frac{E}{R_T}=kM_T\theta_T$

Therefore,

$$I_T=\frac{M_T\theta_T}{M_s\theta_s}I_s$$

or

$$E\left(\frac{1}{R_s}e^{-\frac{T}{R_SC}}+\frac{1}{R_s+R_c}\right)=\frac{M_T\theta_T}{M_s\theta_s}\times\frac{E}{R_s}$$

and, finally,

$$R_c=\left[\frac{\theta_sM_s}{M_T\theta_T-M_s\theta_se^{-\frac{T}{R_SC}}}-1\right]R_s \qquad (4)$$

Equation 4 thus expresses the insulation resistance of the cable free from charging current and dependent only upon those factors of the insulating material which produce an effective conductivity and loss (where R_c is the 1-minute insulation resistance, T in equation 4 is 60 seconds).

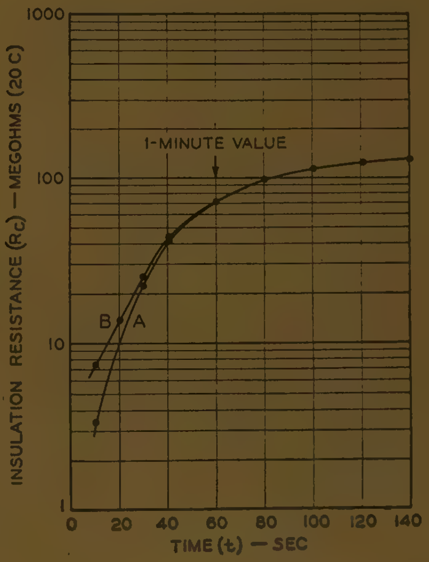
When equations 1 and 4 are compared, it is apparent that the magnitude of the charging current error depends on the value of the standard calibrating resistance, the capacitance of the cable or capacitor, and the elec-

Figure 6. Effect of charging current on measured insulation resistance

Five-microfarad paper capacitor

A—Measured insulation resistance

B—Insulation resistance corrected for charging current error



trification time. An expression for the error in insulation resistance due to charging current, in per cent of the insulation resistance may be set down readily as follows:

$$X=\frac{R_c}{R_s}e^{-\frac{T}{R_sC}}\times 100 \tag{5}$$

Figure 4 shows values of X as a function of the ratio of 1-minute insulation resistance to standard calibrating resistance for different values of time constant (R_sC). From these curves it is clearly evident that for a high resistance test object, with capacitance more than 5 microfarads, one definitely must take into account the error introduced by charging current. For example, if a 1-megohm calibrating resistor is used, a 5-microfarad sample with a 1-minute insulation resistance on the order of 10,000 megohms will exhibit a measurement error of more than 6 per cent. That is, the measured insulation resistance will be low by more than 6 per cent. If the 5-microfarad capacitor had a 1-minute insulation resistance on the order of 100,000 megohms, the charging current error would amount to more than 60 per cent.

Figure 5 shows maximum sample capacitances which, for the usual values of instrument calibrating resistance and sample insulation resistance, will keep the charging current error at 1 per cent or less. The 0.1-megohm standard resistance permits a much higher sample capacitance for a given charging current error, although a 1-megohm standard from an instrumentation standpoint usually is accepted as being the more desirable. Concerning manipulation of the galvanometer shunt, a word of caution is necessary. As most Ayrton shunts have an infinite position immediately adjacent to the zero position, it is well to make certain that the shunt is on its zero position when the measuring circuit first is energized and the stop watch started. If the shunt is standing on its infinity position, there will be no closed circuit until the shunt arm is shifted, and not only will the 1-minute timing be short, but also the charging current error will be correspondingly greater.

It is possible also to short-circuit the standard calibrating resistance or introduce a low resistance for a short period at the start of the electrification and before the galvanometer is connected into the circuit. If the capacitor or cable to be measured has a very large capacitance, this will impose an excessive drain on the d-c supply and should be taken into account. However, if the standard resistance is short-circuited, the time constant is reduced sharply, and the charging current error for almost any size capacitor becomes negligible. Most commercial insulation test sets provide means whereby this may be accomplished.

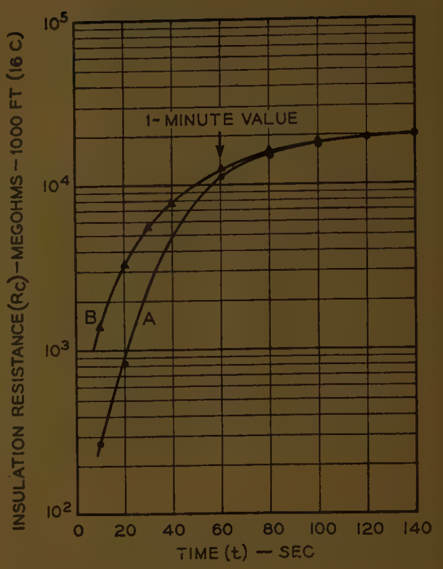


Figure 7. Effect of charging current on measured insulation resistance

Ten 1-mile reels of rubber-covered communication wire measured in parallel

A—Measured insulation resistance

B—Insulation resistance corrected for charging current error

Figure 6 shows the time variation of insulation resistance of a 5-microfarad paper-oil capacitor in a circuit having a 1-megohm calibrating resistor. Two curves are shown, one the measured resistance values and the other the actual insulation resistance values corrected for charging current error. The curves extend from 10 seconds (the earliest practical reading time with a galvanometer) to several minutes. The difference in the two curves decreases sharply with increase of time; at 60 seconds the error is inappreciable. Figure 7 shows the same type of data for a group of 1-mile reels of twisted pair communication cable. In this test, ten such reels were immersed in water, and the 1-minute

Table I. Current Components During D-C Charging of a Dielectric

Current Component	Arises From	Initial Value	Variation With Time	Variation With Temp	Variation With Voltage	Remarks
1. Normal charging current	Normal polarization	High, limited only by external series resistance	Decays to zero exponentially, depending on time constant of circuit	Practically none	Proportional	Same for both charge and discharge. All capacitors have this—even a vacuum capacitor
2. Reversible absorption current	Dielectric absorption	High	Decays to zero as a complex function of the time	Increases markedly with temp	Increases, but does not obey Ohm's law	All solids exhibit this. The better the dielectric, the larger the relative magnitude of this component
3. Irreversible absorption current	Electrolytic-type ions	High or low	Decays to zero slowly as a negative exponent of time	Increases greatly with temp	Increases, but does not obey Ohm's law	All liquids have it. Solids less so
4. Leakage conduction current	Free ions	High or low	Constant	Increases greatly with temp (power function)	Obeys Ohm's law at low stresses only	Gases usually exhibit none. All other materials have it more or less

insulation resistance of all conductors to water taken simultaneously. Ordinarily, the procedure is to multiply the result by 20 and express it in terms of megohms—1,000 feet per conductor. However, the high capacitance of the paralleled cables (totaling 8.3 microfarads) charging through a calibrating resistor of 1 megohm causes a relatively large error in the 1-minute insulation resistance. Hence, for tests of this nature, either the charging current error must be evaluated or means provided for temporarily shunting the calibrating standard resistance by a resistance of much lower value.

CHARGING CURRENT IN LONG CABLES

Insulation resistance measurements sometimes are made on long transmission or communication lines and cables. For a long cable, the charging current error equation previously developed is not theoretically applicable, as the distributed nature of the cable constants must be considered as well as their magnitudes.

When a steady source of electromotive force is applied to a long cable, the entire dielectric medium of the line absorbs charge neither simultaneously nor equally. Owing to a finite velocity of energy propagation along the cable, the dielectric medium charges progressively from the sending end outward. Under these circumstances the sending-end current on a long line must flow progressively over more and more conductor resistance to supply the geometrically distributed capacitance. A time retardation of the charging current thus will result, varying with both the length of the line and its characteristics. Moreover, any series resistance at the sending end—over which the entire cable charging current must flow—will cause further time retardation of the charging. Consequently, the usual 1-minute insulation resistance measurement made on such a long line may contain a large proportion of charging current which enters as an error to give too low a value. Because, as previously mentioned, the galvanometer measures both leakage and charging current after closure of the circuit, it is necessary to subtract the 1-minute charging current in order to obtain the true 1-minute insulation resistance.

Solution of the transient response of a long cable with appreciable terminal resistance to a suddenly applied constant potential is not simple. As the far end of the cable is open, reflections will occur at both ends, the number of such reflections being a function of the propagation velocity divided by the line length. The input current at first will rise sharply and then oscillate downward gradually damping and approaching the final or long-time leakage current value.

Fortunately, lines of moderate length may be treated for charging current error in the same way as shown previously without too much discrepancy. Tests on 17 miles of twisted pair communication cable in water with a total capacitance of 5 microfarads indicate that equations 4 and 5 yield approximately correct results.

REFERENCES

1. Lectures on Dielectric Theory and Insulation (book), **J. B. Whitehead.** McGraw-Hill Book Company, Inc., New York, N. Y., 1927.

2. **W. V. Siemens.** *Poggendorf Annalen der Physik,* (Leipzig, Germany), volume 125, 1865, pages 137–39.

X-Ray Image Storing Phosphors

Phosphors may be produced which store energy from X rays, beta rays, gamma rays, and visible light, and which hold this energy for indefinite periods of time. The energy is released, in the form of light varying from red to ultraviolet, by infrared radiation with speed of release governed by intensity of the infrared radiation.

The effects may be employed in radiography. The X rays are caused to pass through the subject into the phosphor plate or screen, and by differential intensity record in detail thereon producing a latent image.

In an adjoining room, away from the harmful radiation, and at the convenience of the operator, the image is made visible to the eye by irradiating the plate with infrared radiation. If a particular area of the image is of special interest to the technician, he may expose it separately with an infrared spotlight (photographic masking technique is also applicable here).

If a permanent record of the X-ray image is desired, it is an inexpensive and simple task to expose the phosphor image directly to a sensitized paper (sensitive in the color region of the particular phosphor in use). This eliminates the need for double emulsion X-ray film.

These developments were reported recently in the *Journal of Applied Physics* by O. E. Berg and H. F. Kaiser of the Naval Research Laboratory, Washington, D. C., who have been investigating phosphors for X-ray energy storage characteristics. The materials for these experiments were furnished by the Brooklyn Polytechnic Institute.

The results of these experiments have revealed numerous possibilities of infrared phosphors in radiography. Phosphorography will not immediately replace X-ray films or the fluorescent screen, however it will supplement these methods and be particularly valuable in special cases. For example, flash fluoroscopy will be possible with the high current capacitor discharge X-ray tubes, whereby an image made with a very short X-ray exposure of high intensity will be made immediately visible and retained long enough for inspection or recording on paper or film.

INSTITUTE ACTIVITIES

Pacific General Meeting Offers Attractive Vacation Features

The AIEE San Diego Section, host for the Pacific general meeting to be held in San Diego, Calif., August 26–29, 1947, is making the theme of its invitation, "Plan your vacation for the dates of the meeting and stay around as long as you can." Headquarters for the meeting will be in the San Diego Hotel. An attractive program of entertainment, sports, and trips, with special features for the visiting women, has been arranged. A tentative schedule of events was published in the June issue of *ELECTRICAL ENGINEERING* (*p 596*).

Few areas can offer as broad an array of recreational activities as San Diego. The bathing beaches—Del Mar, La Jolla, Pacific Beach, Mission Beach, and Coronado—are attractions for swimmers and sun worshippers. Fishermen have the choice of lakes and streams in the mountains back of the city, or grappling with the big ones off sport fishing boats that ply every day out of San Diego Harbor in the summer time. For the golfer, there are eight first-class courses within 20 miles of downtown. Old Mexico is just 18 miles by automobile from San Diego, and no passports are required to cross the border. In addition to attractive cafes and shops and the Latin atmosphere of Tijuana, the spirited Basque game of Jai Alai has been started this year and plays to large crowds four nights per week. Horse racing at Del Mar Turf Club, 20 miles north of San Diego, will be in session all during the meeting week.

The new and the old in navigation: a portable radar unit from the Navy Electronics Laboratory on Point Loma passes the Old Lighthouse which guided ships around the end of the Point for many years after its construction in 1853

The largest industry in San Diego is the United States Navy, with a property investment of over $300,000,000, and installations giving employment to thousands, both in and out of uniform. The Naval Air Station, on one of the arms of land surrounding San Diego Bay, contains extensive aircraft repair facilities, and docking space for the several flattops regularly stationed in port. In addition to active destroyers, submarines, and tenders stationed in the Bay, more than 300 inactive vessels are tied up at the Naval Repair Base as a reserve fleet. The Naval Training Center is one of three in the United States where enlisted men receive their first "boot" training. The Naval Hospital, in Balboa Park, is one of the largest in the world. The Naval Electronics Laboratory, on Point Loma, is a relatively new establishment, where civilian scientists and engineers conduct research and development on radar, sonar, communications, and other electronic applications.

Included among the inspection trips scheduled, but not yet established as to exact times, are

Naval Electronics Laboratory: Established in San Diego in 1940, the Laboratory is now the workshop of several hundred engineers, scientists, and technicians doing design, procurement, testing, installation, and maintenance of electronic equipment for the United States Fleet.

Consolidated-Vultee Aircraft Corporation: Birthplace of the Liberator and Dominator bombers, and of the Catalina and Coronado naval patrol aircraft. Convair now is making a large production run of a 40-passenger transport, and is bringing to completion the XC-99, largest airplane in the world.

Silver Gate Station: Newest generating plant of San Diego Gas and Electric Company, where one 35,000-kw generator is in operation, and a second unit of 50,000 kw is being installed.

Solar Aircraft Company: Stainless steel fabricators, and largest manufacturers in the world of aircraft exhaust manifolds.

Naval Air Station: Across the bay from San Diego, on North Island. Complete facilities for disassembly and repair of aircraft and aircraft engines. Training base and home of fleet air force. Visit will include inspection trip aboard an aircraft carrier.

Naval Repair Base: In the southern part of San Diego Bay. Complete maintenance facilities for destroyers, submarines, and other small craft, and site of a more than 300-vessel reserve fleet.

The Pacific general meeting committee is planning a program that will be announced in detail in the August issue of *ELECTRICAL ENGINEERING* and which will be directed to helping visitors enjoy as many of the attractions of the community as possible.

Annual Additions to List of Members for Life

Membership for life is granted by the AIEE to members who either have paid annual dues for 35 years, or have reached the age of 70 and have paid dues for 30 years. A list of those who have become members for life during the preceding year is published annually in *ELECTRICAL ENGINEERING.*

Institute members who have attained the status of member for life since publication of the last list in the July 1946 issue are the following:

L. W. Abbott
P. H. Adams
P. G. Agnew
V. E. Alden
Sydney Alling
W. L. Amos
E. R. Anderson
E. R. Armstrong
K. A. Auty
G. K. Bailey
Guy Baker
H. S. Baker
A. F. Bang
P. H. Bardill
T. F. Barton
C. C. Batchelder
B. C. Batcheller
W. A. Black
H. E. Boatright
F. G. Boyce
R. D. Brackett
D. L. Brundige
H. E. Bussey
F. V. Carleton
P. H. Chase
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J. A. Dienner
F. C. Doble
G. G. Dobson
J. M. Drabelle
R. W. Drake
W. L. DuBois
Wray Dudley
H. B. Dwight
L. C. Eddy, Jr.
L. L. Edgar
Ralph Elsman
G. M. Evans
W. E. A. Foreman
H. A. Frederick
F. M. Fuller
L. F. Fuller
L. A. Gary
W. H. Geiger
R. J. Graf
E. A. Graham
G. H. Gray
R. C. Gray
H. V. Green
A. E. Greenawalt
P. H. Harding
O. A. Havill
L. A. Hazeltine
A. H. Heitmann
J. G. Hirsch
R. H. Hopkins
H. C. Hoyt
R. S. Hoyt
G. S. Jacobs
C. H. Jones
D. W. Jones
E. C. Jones
W. C. Kalb
C. L. Kasson
A. H. Kehoe
B. E. A. Kelso
H. S. Knowlton
Ludwig Kummer
H. S. Lane
H. J. Laurencot
E. F. Leahey
B. F. Lee
W. F. Lent
H. P. Liversidge
A. C. Lockwood
J. E. Lowry
G. L. Lubbert
F. W. Maononey
W. E. Mashburn
R. B. May
W. R. McGovern
M. J. McHenry
John Mills
J. H. Morice
George Moser
J. N. Murray
C. A. Nash
Eugene Ogur
M. C. Olson
S. D. Packard
Robert Palmer
R. C. Patton
D. M. Petty
E. W. Petty
P. H. Pierce
Anthony Pinto
C. J. Pope
G. E. Quinan
W. J. Quinn
M. V. Read
P. O. Reyneau
S. R. Rhodes
A. H. Robbins
A. R. Robison
C. D. Robison
C. E. Rogers
H. W. Rogers
L. D. Rowell
C. F. Scott
W. J. Shackleton
G. F. Sills
E. D. Stewart
R. W. Tassie
G. N. Thomas
Gordon Thompson
E. B. Thurston
C. P. Tolman
F. W. Uhl
H. L. Unland
E. E. Valk
I. H. Van Horn
William Volkmann, Jr.
E. B. Wagner
A. E. Waller
C. S. Wendell
F. W. H. Wheadon
R. S. Wilbur
R. P. Winton
G. R. Wood
M. R. Woodward
J. W. Wopat
Otto Wortmann
J. C. Wright
J. L. Wright
George Wrigley
F. T. Wyman
C. R. Yuill
A. R. Zimmer

An inspection trip to Wright Field is included among the items scheduled for the Middle Eastern District meeting to be held September 23–25, 1947, in Dayton, Ohio. Shown at right is a 110-inch wheel and brake assembly in a dynamic test setup in one of the laboratories at the field. Motors and aircraft applications papers will be featured at the meeting

AIEE Proceedings Being Ordered

Second AIEE *PROCEEDINGS* order forms have been coming in since the first week in June. The second order form was published last month (*EE, June '47, pp 55A and 56A*) and covered the North Eastern District meeting and the summer general meeting technical papers.

As before, production will be delayed on those papers that have discussions in order to allow time for review and processing. Papers without discussion are being published as rapidly as possible. Tardy submission of orders will delay distribution because of lack of information concerning the demand for a particular paper. First AIEE *PROCEEDINGS* order forms covering winter meeting technical papers (*EE, Feb '47, pp 33A and 34A*) still are being received at the present time.

Future AIEE Meetings

Pacific General Meeting
San Diego Hotel, San Diego, Calif., August 26–29, 1947

Middle Eastern District Meeting
Biltmore Hotel, Dayton, Ohio, September 23–25, 1947

Midwest General Meeting
Congress Hotel, Chicago, Ill., November 3–7, 1947

Winter General Meeting
William Penn Hotel, Pittsburgh, Pa., January 26–30, 1948

New AIEE Technical Committee Structure

Recommendation of the committee on planning and co-ordination for a revised basis of AIEE technical committee structure has been approved by the board of directors. Announcement of the change was made last month (*EE, June '47, pages 597–8*). The new organization which is currently being set up for the administrative year 1947–48 is as follows:

Power Group

1. Power rotating machinery committee
2. Power transformers and regulators committee
3. Power generation committee
4. Power system operation committee
5. Power transmission and distribution systems committee
6. Insulated power cables committee
7. Power protective devices committee
8. Power switchgear committee
9. Power relays committee
10. Power systems application of carrier current committee
11. Power converters—electronics committee
12. Power substations committee

General Applications Group

1. Air transportation committee
2. Domestic and commercial applications committee
3. Land transportation committee
4. Production and application of light committee
5. Marine transportation committee

Industrial Group

1. Electric welding committee
2. Electric heating committee
3. Industrial power systems committee
4. Mining, metal forming, and rolling committee
5. Industrial control devices and equipment committee
6. Chemical, electrochemical, and electrothermal committee
7. Machine tools, materials processing, and fabrication committee

Communications and Science Group

1. Communications committee
2. Basic sciences committee
3. Electronics committee
4. Instruments and measurements committee
5. Nucleonics committee
6. Therapeutics committee

Total, 30 technical commmittees; four groups

Second Lightning Reference Volume Cancelled

Work on the proposed second volume of the AIEE Lightning Reference Book has been suspended indefinitely. The small number of potential purchasers, and the current high printing and publication costs, make the per volume cost prohibitive. Consequently, the project has been temporarily withdrawn from active status.

DISTRICT • • • • •

North Central District Student Conference

The University of Wyoming, Laramie, was the site of the North Central Student conference held on April 25–26, 1947, and attended by some 85 delegates and visitors. Professor R. O. Trueblood (A '32) chairman of student activities, presided over the conference. Welcome addresses were delivered by Doctor Goodrich, dean of engineering, and Doctor Humphreys, president of the University of Wyoming. Doctor Humphreys spoke briefly on the debt civilization owed to electrical engineers. H. F. Gidlund (M '42) secretary, AIEE North Central District, responded on behalf of the AIEE to the warm welcome extended by the University of Wyoming.

Student Chairman Ritler introduced the authors of student papers. The following papers were presented:

"Copper Oxide Rectifiers as Modulators," by Neil Partridge, University of Wyoming.

"The Ignitron Rectifier" (graduate paper) by Donald Gade and R. Ibata (A '41), University of Nebraska, Lincoln.

"Intermodulation Analysis of Audio Systems" by G. L. Carrington, University of Colorado, Boulder.

"Voltage Regulator for Electronic Exciter" by J. Wheatley and R. Mathias, University of Colorado.

Some 95 persons attended the industrial applications session at the North Eastern District meeting held on April 23-25, 1947, in Worcester, Mass. Shown here (left to right) are F. D. Snyder (A '45), F. L. Reed (A '42), V. F. P. Sepavich (A '37), J. G. Roby, and R. M. Scott who participated in the session. Chairman Sepavich presided and the other men presented papers

A sound motion picture on ground controlled approach plane control also was shown.

The student counselors meeting was preceded by a dinner for all student counselors, faculty members, and District officers. Among the business matters discussed, it was decided that the District student conference to be held in the spring of 1948 would take place at Denver University. John Martin of Denver University was nominated District chairman of student activities for 1947–48.

Three more papers were read at another technical session. The items presented were

"A Five Channel Electronic Switch" (graduate paper), by R. D. Goodrich (A '46), University of Colorado.

"Automatic Speed Regulation of a D-C Motor" by Paul Johrde and R. Dennis, University of Nebraska, (laboratory demonstration and presentation by Paul Johrde).

"Sonar, Underwater Ears of the Fleet" by S. K. Williams, South Dakota School of Mines and Technology, Rapid City.

Two Signal Corps films on radar were shown.

The student conference banquet was held in the Union Building at the University with Professor Trueblood presiding. Prizes were awarded by H. F. Gidlund, secretary of the District to the following authors:

FIRST PRIZE (graduate paper): R. D. Goodrich, University of Colorado.

SECOND PRIZE (graduate paper): Donald Gade and Ralph Ibata, University of Nebraska.

FIRST PRIZE (undergraduate paper): John Wheatley and Robert Mathias, University of Colorado.

SECOND PRIZE (undergraduate paper): S. K. Williams, South Dakota State School of Mines.

District Secretary Gidlund who is affiliated with the Public Service Company of Colorado, Denver, spoke on "Installation and Operation of 20,000-Kva Hydrogen-Cooled Synchronous Condenser." His talk was illustrated by slides and motion pictures.

Southern District Student Branch Conference

Some 250 students and 16 faculty counselors were present at the annual Southern District conference of Student Branches which was held at the University of Kentucky in Lexington, on April 3–5, 1947. Professor Brinkley Barnett (A '20) chairman of the committee on student activities in the Southern District for the year 1946–47, presided over the meeting.

Student Branch members conducted inspection tours of the laboratory and building of the engineering college including the University of Kentucky's frequency modulation station *WBKY*.

A smoker was held in honor of the visiting delegates which featured a get-acquainted hour, colored motion pictures of the University of Kentucky, and card tricks.

The technical session, presided over by Professor M. G. Northrop (M '46) chairman of the student papers committee, featured six student papers:

"Investigations of Thyrite," by Robert C. May, Duke University, Durham, N. C.

"Differentiating and Integrating Circuits," by Henry Gleixner, University of Kentucky.

"Closed Cycle Applications of the Amplidyne," by T. M. Greer and A. R. Jones, Clemson Agricultural College, Clemson, S. C.; presented by A. R. Jones.

"Atomic Generation of Electrical Energy," by E. Flynn

Menius, Jr., North Carolina State College, Raleigh.

"Mechanical Calculators for Advanced Mathematics," by J. S. Hunter, North Carolina State College.

"An Electronic Means of Phase Angle Measurement," by H. Rosen and H. Grossimon, Tulane University of Louisiana, New Orleans, presented by H. Grossimon.

At a banquet which was held in the ballroom of the Phoenix Hotel, Chairman Howard Stewart of the University of Kentucky Branch, acting as toastmaster, introduced the visiting faculty counselors and welcomed all the delegates on behalf of the Branch. Professors Bureau (M '33) and Barnett of the University of Kentucky were introduced and Dean D. V. Terrell gave the welcome address. Southern District Vice-President H. B. Wolf (F '45) commented upon the manner in which the student convention had improved over a period of years and then presented prizes for the best student papers as follows:

FIRST PRIZE: Robert C. May, Duke University.

SECOND PRIZE: Henry Gleixner, University of Kentucky.

THIRD PRIZE: J. S. Hunter, North Carolina State College.

H. N. Muller (M '43) manager of graduate student training, Westinghouse Electric Corporation, spoke on "Engineers—Don't Build Fences," referring to the mental types concerning specialization or locale for work which limit young engineers' progress. An informal dance was held after the dinner.

Professor M. O. Leffell (M '44) of the University of Tennessee was nominated to fill the office of chairman of student activities for the Southern District for 1947–48 and also the office of the delegate to represent the Southern District committee on Student activities at the conference of officers, delegates, and members in June for the year 1947–48.

When business matters had been completed, a lecture on "Mechanical Analogy of Transmission Line Surges due to Lightning" was presented by H. N. Muller, using a mechanical analyzer as an aid. With this machine he was able to explain what lightning actually is and to show the effects of lightning upon the wave forms already existing in transmission lines. A discussion period followed the talk.

A number of people who attended the convention made tours of the bluegrass country including visits to famous horse farms and Mary Todd Lincoln's home.

Great Lakes District Student Conference

The student conference of the Great Lakes District was held at the University of Notre Dame, South Bend, Ind., May 2, 1947. For the first time, winners in the District student paper contest of that day were announced before the end of the conference. Four graduate and eight Branch papers were entered and presented. All were so uniformly excellent that the five judges deliberated for well over an hour before announcing their winners.

First place winners in both groups were awarded the prizes forthcoming from headquarters. Second and third place cash awards were made from funds furnished by the District. About 100 students and counselors attended, and all who commented to Professor L. F. Stauder (M '43) of the University of Notre Dame or to Professor J. Gault (F '46) of the University of Michigan, Ann Arbor, who jointly had charge of arrangements, were highly in favor of continuing the plan. Its prime purpose was that of simulating the presentation of student papers. Its full influence cannot be judged until a year hence but most of those present left with plans for even more student papers to be presented throughout the year and placed in competition for District awards in 1948.

Winners of the graduate paper prizes were as follows:

FIRST PRIZE: R. B. Edgar, Northwestern University, Evanston and Chicago, Ill., for the paper "Design of Unilateral Mutual Impedances."

SECOND PRIZE: G. I. Cohn, Illinois Institute of Technology, Chicago, for the paper "Paradoxes of Electromagnetic Induction."

Winners of undergraduate paper prizes were:

FIRST PRIZE: H. M. McConnell, Marquette University, Milwaukee, Wis., for the paper "Progressions Applied to Engineering Problems."

SECOND PRIZE: John W. Huston, Iowa State College, Ames, for the paper "Calculating Resistances for D-C Magnetic Starters by Graphical Solution."

THIRD PRIZE: J. R. Boulton, University of Iowa, Iowa City, for the paper "Color Television."

Doctor T. G. LeClair (F '40) vice-president of the AIEE Great Lakes District, addressed the conference at the student paper sessions. He spoke on "Results of Nationwide Survey of AIEE Members on Organization of the Engineering Profession." At a dinner which concluded the conference Doctor LeClair spoke again, this time on "Engineers and Our Standard of Living."

Pictured (left to right) are Vice-President T. G. LeClair; Professor W. N. Gamble, South Dakota State College; and winners in the student paper contest of Great Lakes District: R. B. Edgar, Northwestern University; H. R. Robbins, University of Illinois; J. R. Boulton, University of Iowa; John W. Huston, Iowa State College; G. I. Cohn, Illinois Institute of Technology; and Myles E. Wood, University of Notre Dame

SECTION ● ● ● ● ● ●

Portland Section and Student Branch Meet

The Portland (Oreg.) Section held its traditional annual meeting with the Student Branch, Oregon State College, Corvallis, on Saturday, May 24, 1947. Thirty-five members together with families and guests made the 80-mile trip.

The afternoon events included a conducted tour through the Northwest Electrodevelopment Laboratory of the Metallurgical Branch of the Bureau of Mines at Albany, Oreg. Much interest was shown by the members in the various processes under development in the laboratory.

For those interested in golf, the annual competition for the Dearborn Cup was held at the Corvallis Country Club. H. A. Wakeman was winner of this event.

A dinner, held at the Benton Hotel, afforded the members a chance to meet the students socially. At this time the Dearborn Cup was presented to H. A. Wakeman and Dean Gleason, of the school of engineering, addressed the group briefly on the problems facing educational institutions.

At the joint meeting in the evening, technical papers were presented by the students and the prize for the best paper, first year membership in the Institute, was won by W. R. Singletary and J. A. Capps for their paper "Effects of Very High Temperatures on Transformer Core Loss."

Evening entertainment for the visiting women was held at the home of Professor (F '32) and Mrs. F. O. McMillan.

20th Steinmetz Memorial Lecture Delivered by Doctor Compton

Doctor Arthur H. Compton, chancellor of Washington University, St. Louis, Mo., delivered the 20th Steinmetz Memorial Lecture on the subject "The Human Meaning of Atomic Energy," on Tuesday evening, May 27.

This lecture sponsored by the Steinmetz Memorial Foundation is the 20th of a series of lectures by eminent scientists and engineers in honor of Charles Proteus Steinmetz, whose personality and achievements thus are recalled periodically to the engineers of the nation. The lecture was held in Memorial Chapel, Union College, Schenectady, N. Y. The trust is under the administration of the AIEE Schenectady Section.

BRANCH

Student Branches of New York City District Meet

On Friday, May 2, 1947, the Third District AIEE and the New York Section jointly sponsored an AIEE Student Branch meeting.

An interesting program integrated around manufacturing for communication was provided by the committee on arrangements under the chairmanship of J. A. Duncan, Jr. (M '44) of the American Telephone and Telegraph Company. The students from the ten Branches in the Third District met at 10 a.m. at the Western Union auditorium, 60 Hudson Street, New York, N. Y. John H. Pilkington, chairman, New York Section, presided. Following the showing of a motion picture entitled "The Telephone Hour", the three students papers that had been judged worthy of prizes were presented by the student authors. These presentations were followed by a second film on "Coaxial Cable" and a talk by T. H. Clark, International Telephone and Telegraph Company, covering the highlights of the afternoon inspection trip to the Nutley, N. J., plant of the Federal Telephone and Radio Corporation. The students then were taken to Nutley by bus where the visitors were conducted through the manufacturing plant. Opportunity was given to observe engineering, manufacture, assembly testing, and shipping of dial telephone and mobile radio apparatus and systems.

After the factory inspection the research laboratories of the Federal Telecommunication Laboratories, Inc., were visited. A buffet supper was served before the return to New York for the evening meeting.

Those who preferred a trip to a large power generating station had an opportunity to visit the Waterside Station of the Consolidated Edison Company.

The evening session was held at the Western Union auditorium with J. L. Callahan (M '35), secretary of the New York City District presiding. The presentation of the prize paper awards as judged by a committee of five under chairmanship of J. E. Goodale (F '34) was made by Doctor O. E. Buckley (F '29) president of the Bell Telephone Laboratories, Inc., and vice-president of the New York City District, as follows:

FIRST PRIZE: Milton F. Pravda, Newark College of Engineering, Newark, N. J., for the paper, "Graphical Method of Determining the A-C Resistance in Single Layer Coils."

SECOND PRIZE: Alan Sobel, Columbia University, New York, N. Y., for the paper, "Short Telephone Lines in Broadcast Operation."

THIRD PRIZE: Thomas L. LaGuidice, Polytechnic Institute of Brooklyn, N. Y., for the paper, "Supersonic Waves and Their Application."

In a talk on "Engineering for Manufacture," Doctor H. Rossbacker, Kearny Engineer of Manufacture, Western Electric Company, outlined some of the organizational problems involved in engineering for the production of communication systems. The talk was well received and a lively discussion ensued.

STANDARDS

Neutral Grounding Devices Standard

The proposed AIEE Standard on neutral grounding devices now has been approved. Listed as being effective May 15, 1947, it is titled "Standard For Neutral Grounding Devices," and is listed as AIEE Standard 32.

ABSTRACTS

prepared by the authors of the papers and approved by the technical program committee.

Abstract Received of Final Summer Paper

The following abstract of a summer technical paper was not received in time for publication in the June issue of *ELECTRICAL ENGINEERING.*

Communication

47-140-ACO—Radio Interference Supression in Canada; *H. O. Merriman. 20 cents.* Man-made static has been found, in many instances in Canada, to constitute a limiting factor in radio communication. The paper describes means adopted in Canada for the suppression and control of radio interference from many sources such as electrical appliances, high voltage power lines, and electromedical equipment. Committees of the Canadian Standards Association now are preparing a series of specifications dealing with methods of measurement and tolerable limits of interference from various sources.

PERSONAL

Philip Sporn (A '20, F '30) formerly executive vice-president, American Gas and Electric Service Corporation, New York, N. Y., has been elected president of the corporation and of the American Gas and Electric Company. Mr. Sporn also recently received the honorary degree of doctor of engineering from Stevens Institute of Technology. A 1917 graduate of Columbia University, Mr. Sporn joined the company in 1920, becoming chief electrical engineer in 1927. He was named chief engineer in 1933, vice-president in charge of all engineering activities in 1934, and executive vice-president in 1945. Mr. Sporn is credited with a major part in the evolution of the company's exceptionally co-ordinated interconnected power system. He has done much original work in the field of power supply, distribution, and protection. In 1937 he proposed the ultrahigh speed closure of circuit breakers as a means of furthering stability and dependability of high voltage transmission circuits. He has carried out pioneer developmental work in the application of hydrogen to the cooling of alternators and synchronous condensors. Mr. Sporn also has been instrumental in effecting several installations of the heat pump on the American Gas System as an indispensable element in the complete electrification of the home. Recipient of the AIEE Edison Medal in 1945, Mr. Sporn has been active in AIEE committee work and is the author of numerous technical papers, for one of which he received the AIEE national best paper prize in 1928. In 1946 Mr. Sporn was awarded the Egleston Medal of the Columbia Engineering Alumni Association for distin-

Philip Sporn

guished engineering achievement. He is a member of the American Society of Mechanical Engineers, the American Society of Civil Engineers, Franklin Institute, the American Society for the Advancement of Science, Sigma Xi, and Tau Beta Pi.

Matthew Luckiesh (A '11, F '40) director of the lighting research laboratory, General Electric Company, Cleveland, Ohio, has been awarded the Gold Medal of the Illuminating Engineering Society for 1947. The announcement of the award read: "Doctor Luckiesh's achievement as a research physicist in the realm of illumination and vision are acknowledged throughout the world. His researches over the past 36 years have resulted in vast new concepts of vision, new techniques of research and instruments of measurement. The establishment of a sound science of seeing, given substance by his findings, has been one of the great advances in the illuminating engineering profession. Similarly distinguished and fundamental has been his work in the technology of radiation below and beyond the visible, particularly in the germicidal and therapeutic ultraviolet wave length." Doctor Luckiesh has published some 23 books and many technical papers on his studies. He is a fellow and past president of the IES. He also is a member of the American Association for the Advancement of Science, the American Physical Society, Franklin Institute, the Optical Society of America, and the United States National Committee of the International Commission on Illumination. He holds honorary degrees from Iowa State College and Purdue University.

T. A. Worcester (A '06, M '25) assistant manager, central station engineering department, General Electric Company, Schenectady, N. Y., has retired. Mr. Worcester, who graduated from the University of Cincinnati in 1904, joined the company as a test engineer in 1905. In succeeding years he was particularly concerned with the design and application of lightning arresters and power transmission systems. Active in AIEE affairs, Mr. Worcester served for many years on the transmission and distribution committee.

I. F. Baker (M '19) formerly assistant to the vice-president, Westinghouse Electric International Company, New York, N. Y., has been appointed a vice-president of the company. With the company since 1909, Mr. Baker was stationed in Japan between 1919 and 1927 and in the latter year was appointed manager for the Far East in New York. He was sent to London, England, as European manager in 1930, returning to New York in 1937. Mr. Baker will continue as treasurer and director of the company.

E. O. Shreve (A '04) vice-president, General Electric Company, Schenectady, N. Y., has been elected president of the United States Chamber of Commerce. Mr. Shreve, who will be the first full-time president of the chamber, has been granted a year's leave of absence by the General Electric Company. A graduate of Iowa State College, Mr. Shreve joined the General Electric Company in 1904 and, after completing the student course, was transferred to the Pacific Coast where he served the company in various sales positions, becoming manager of the San Francisco (Calif.) office in 1917. He was transferred to Schenectady in 1926 as manager of the industrial department. In 1934 he was appointed vice-president. Mr. Shreve has been active in the National Electrical Manufacturers Association, the American Management Association, the National Fire Protection Association, and the New York State Chamber of Commerce.

A. H. Frampton (A '21, F '45) formerly assistant chief engineer, electrical engineering department, Hydro-Electric Power Commission of Ontario, Toronto, Canada, has been made director of engineering. Mr. Frampton, who was born in England, received the degree of bachelor of arts in science from the University of Toronto in 1925. Previously he had been employed as an assistant in the Commission's laboratory, and, after receiving his degree, was appointed assistant engineer for the station section of the electrical engineering department. He was appointed assistant to the chief electrical engineer in 1930 and assistant chief engineer of the electrical engineering department in 1938. Mr. Frampton has had much to do with planning the engineering department's course of work for junior engineers and recently co-operated with the University of Toronto in planning a course on electric power systems.

Fulton Cutting (M '17) of New York, N. Y., former president and chairman of the board of directors of the Colonial Radio Corporation, Buffalo, N. Y., has been appointed assistant to the president for research and professor of physics at Stevens Institute of Technology, Hoboken, N. J. He holds the degrees of bachelor of arts, master of arts, master of electrical engineering, and doctor of science from Harvard University. During World War I, Mr. Cutting worked with the Bureau of Aircraft Production and afterwards was president of Cutting and Washington, Inc., radio manufacturers. In 1924 he organized the Colonial Radio Corporation, became its president, and later chairman of the board of directors. He terminated this association in 1944. From 1941 to the end of the war Mr. Cutting was a member of the operational research staff in the Office of the Chief Signal Officer, United States Army. He is a past president of the Institute of Radio Engineers and has served on the board of directors of the Metropolitan Opera Association, the Prisoners Association of New York, and the New York Trade School.

M. J. McHenry (A '11, M '20) formerly director of sales promotion, Hydro-Electric Power Commission of Ontario, Toronto, Canada, has been appointed director of consumer services. Born in Pennsylvania, Mr. McHenry is a graduate of McGill University. He has been with the Commission since 1938 when he was made director of sales promotion. Previously he had been associated with Smith, Kerry, and Chase, consulting engineers, Toronto; the Canadian General Electric Company, Toronto; the Walkerville (Ontario) Hydro-Electric System; and the Ferranti Electric Company, Ltd. He is a past vice-president of the AIEE and currently is serving as a director. He has served on a number of AIEE committees and was chairman of the committee on transfers for 1943–44. He also is a member of the Association of Professional

I. F. Baker

E. O. Shreve

T. A. Worcester

Matthew Luckiesh

Engineers of Ontario, the Electric Service League of Ontario, the Electric Club of Toronto, and the Canadian Electrical Council.

P. C. Cromwell (A '28) associate professor and acting chairman, electrical engineering department, New York University, New York, has been appointed chairman of the electrical engineering department at the University of Tennessee, Knoxville. Professor Cromwell holds the degrees of bachelor of science from Carnegie Institute of Technology and master of science from New York University. After earlier associations with the Westinghouse Electric Corporation and the Byllesby Engineering and Management Company, he joined the faculty of New York University in 1931 as instructor. He was appointed assistant professor in 1936 and associate professor in 1900. He is the author of "The Speed-Time Electrograph" and a number of technical papers. Professor Cromwell has been active in the affairs of the AIEE New York Section. He is a member of Tau Beta Pi and Eta Kappa Nu.

R. L. Hearn (M '23) formerly executive assistant to the chairman, Hydro-Electric Power Commission of Ontario, Toronto, Canada, has been appointed general manager and chief engineer of the Commission. Mr. Hearn joined the Commission as design engineer in 1913, the year he was graduated from the University of Toronto. He was assistant engineer from 1918 until 1921 when he became assistant chief engineer for the Washington Water Power Company, Spokane. Between 1924 and 1942 he was associated successively with H. G. Acres and Company, Niagara Falls, Ontario, as chief engineer and secretary–treasurer; the Dominion Construction Company; and H. F. McLean, Ltd., as consulting engineer and chief engineer. He returned to the Hydro-Electric Commission in 1942 as executive assistant to the chairman.

John Dibblee (M '26, F '44) formerly chief engineer, executive department, Hydro-Electric Power Commission of Ontario, Toronto, Canada, has been appointed manager of personnel for the Commission. Mr. Dibblee, a graduate of the University of Toronto, joined the Commission in 1917 as station design engineer. After serving in World War I, he became district operating engineer and in 1926 was appointed general superintendent of the Niagara Falls district. He was appointed assistant chief operating engineer in 1931 and assistant chief engineer in 1937. In 1945 he was made chief engineer in charge of operations.

A. W. Manby (A '22, M '32) formerly assistant to the chief engineer, Hydro-Electric Power Commission of Ontario, Toronto, Canada, has been appointed assistant general manager for administration. Mr. Manby, who was graduated from the University of Michigan, joined the Hydro-Electric Commission in 1921 as chief operator at Queenston, Ontario, and subsequently has been superintendent at Chats Falls, chief operator at Toronto, and assistant chief operating engineer. He was appointed assistant to the chief engineer in 1941. He is a member of the Association of Professional Engineers of Ontario.

W. S. Gifford (A '16) president of the American Telephone and Telegraph Company, New York, N. Y., has been awarded the interindustry Wedge Award for 1946. The Wedge Award is presented to a person in any industry whose accomplishments are reflected toward the betterment of mankind. Mr. Gifford was honored for "his remarkable achievement in improving and expanding telephone service, especially long distance, in 1946, without which recovery of the national economy would have been immeasureably retarded if not permanently impaired."

W. F. Hynes (A '07, M '41) Northwestern district sales manager, General Electric Company, Portland, Oreg., has retired. After his graduation from the University of California in 1898, Mr. Hynes traveled throughout the Western hemisphere supervising installation of electric equipment. He joined the General Electric Company, in 1910 and since that time has been assigned to Portland. In 1927 he received the Charles Coffin certificate of merit.

D. J. O'Conor Jr. (A '38) assistant chief engineer, Formica Insulation Company, Cincinnati, Ohio, has been elected a vice-president, assistant to the president, and a director of the company. Mr. O'Conor is cofounder with his father of the Formica Company. He was graduated from Massachusetts Institute of Technology in 1937 and for the succeeding three years was with the Allis-Chalmers Manufacturing Company, Milwaukee, Wis.

R. S. Wallace (A '44) chairman of the board of directors, Central Illinois Lighting Company, Peoria, will retire July 1, 1947. After being graduated from the University of Illinois, Mr. Wallace went to Peoria in 1899 as chief engineer for the Peoples Gas and Electric Company, predecessor of the Central Illinois Company. He has served as chief engineer, department superintendent, vice-president and general manager, president, and chairman of the board.

C. F. Kettering (A '04, F '14) vice-president in charge of research, General Motors Corporation, Dayton, Ohio, has retired. Doctor Kettering currently is director of the Sloan-Kettering Cancer Research Institute, New York, N. Y. He had been associated with the General Motors Corporation since 1920, at which time the corporation acquired the research laboratories which he had established in Dayton in 1916.

D. M. Umphrey (A'36, M '43) formerly assistant chief engineer of the Eugene, Oreg., Water Board and engineer with the Westinghouse Electric Corporation in both East Pittsburgh, Pa., and the Pacific Northwest, has been appointed circuit breaker engineer of the Pacific Electric Manufacturing Corporation, San Francisco, Calif.

H. E. Warren (A '02) inventor of the Telechron motor and founder and president of Telechron, Inc., Worcester, Mass., recently was honored by a 3-hour program held in the Worcester Memorial Auditorium by the employees of Telechron, Inc., celebrating the 30th anniversary of Mr. Warren's invention.

OBITUARY • • • •

Arthur Russell Wellwood (M '22, F '36) lieutenant colonel, Corps of Engineers, United States Army, died March 5, 1947, in Walter Reed Hospital, Washington, D. C. Colonel Wellwood was born May 7, 1888, in New York, N. Y., and attended New York University. He was associated with the Central Hudson Gas and Electric Company Poughkeepsie, N. Y., from 1911 to 1917 as construction engineer, assistant chief engineer, technical assistant to operating superintendent, and operating superintendent. With the outbreak of the first World War he was commissioned lieutenant and served overseas with the Engineers Corps. After the war he returned for a short time to the Central Hudson Company and in 1920 was appointed assistant engineer secretary of the superpower survey of the United States Geological Survey. He joined the firm of Murray and Flood, New York, in 1921, and while with that company prepared reports on the Passamaquody Bay project and the Santee-Cooper hydroelectric project. For this firm he was resident engineer in charge of the construction of the Saluda Dam Hydroelectric Development near Columbia, S. C., said to be the largest earthen dam in the world for power purposes. When this was completed in 1931, he was appointed chief engineer of the South Carolina Power-Rate Investigating Committee and was retained as consulting engineer for several state departments. In 1934 he became regional supervisor for the Electric Rate Survey of the Federal Power Commission, and he was made assistant director of the survey in 1935 and director in 1936. In 1937, after a brief association with the Public Works Administration, Washington, he organized the Wellwood Engineering Company, in Lincoln, Nebr., and Columbia. Called to active duty in 1940, he supervised the construction of many Army camps and served as commandant of the Carolina maneuver area before going to Europe as executive officer of the 347th Engineer Regiment. Colonel Wellwood served more than three years in the European theater and was awarded the Legion of Merit and the Bronze Star medal. Upon his return to the United

States he was assigned to the Repairs and Utilities Division of the Office of the Chief of Engineers in Washington. He had published a number of technical articles and reports among which was the "Report on the Electric Utility Situation in South Carolina." Colonel Wellwood was a charter member of the American Society of Military Engineers and was a member of the South Carolina Society of Engineers.

Morgan Brooks (A '90, M '90, F '13) professor emeritus of electrical engineering, University of Illinois, Urbana, died April 23, 1947, in Washington, D. C. Professor Brooks was born in Boston, Mass., March 12, 1861, attended the Roxbury Latin School, and was graduated from Brown University in 1881 with the degree of bachelor of philosophy. In 1883 he received the degree of mechanical engineer from Stevens Institute of Technology. Between 1884 and 1886 he was engaged in research work with the American Bell Telephone Company, Boston, and during this time was inspector for the first commercial long distance line of copper wire between New York, N. Y., and Philadelphia, Pa. He was engineer for the Electrical Accumulator Company, Boston, from 1886 to 1887 and secretary–treasurer for the St. Paul (Minn.) Gas Lighting Company, from 1887 to 1890. In 1890 he organized the Electrical Engineering Company in St. Paul. He was appointed professor of electrical engineering at the University of Nebraska, Lincoln, in 1898 and professor at the University of Illinois in 1901. He was named professor emeritus in 1929. Professor Brooks served as manager of the Institute from 1907 to 1910 and as vice-president from 1910 to 1912. He was a member of the educational committee of AIEE in 1915–16. From 1917 to 1922 Professor Brooks was president of the Western Unitarian Conference. He was also a member of the American Society of Mechanical Engineers, the Western Society of Engineers, the Illuminating Engineering Society, the Telephone Pioneers of America, Tau Beta Pi, Eta Kappa Nu, and Sigma Xi. He had a number of patents to his credit.

Lyman Foote Morehouse (M '16, F '20) who retired in 1939 from the position of technical representative in Europe for the American Telephone and Telegraph Company, and Bell Telephone Laboratories, Inc., died May 1, 1947, in Newark, N. J. Doctor Morehouse was born in Big Rapids, Mich., October 21, 1874, and received from the University of Michigan the degrees of bachelor of science in 1897 and master of arts in 1904. He was honored with the degree of doctor of engineering in 1934. After four years on the faculty of the University of Michigan, Ann Arbor, he was sent to London, England, in 1906, as transmission engineer for the Western Electric Company. He returned to the United States in 1919 and became equipment engineer for the American Telephone and Telegraph Company and in 1919 was appointed equipment development engineer. He was named assistant director of systems development for Bell Laboratories in 1934, and the next year was sent to Europe as technical representative. An active AIEE member, Doctor Morehouse served as director from 1919 to 1923 and vice-president for 1925–26. Among the many AIEE committees on which he served were: educational, finance, law, research, Edison Medal, Standards, and telegraphy and telephony. He had represented the AIEE on the United States National Committee of the International Electrotechnical Commission and the American Engineering Council. At one time he was a member of the council of the American Standards Association and also was a member of the American Association for the Advancement of Science, Tau Beta Pi, and Sigma Xi.

Robert David Evans (A '21, M '26, F '40) consulting transmission engineer, Westinghouse Electric Corporation, East Pittsburgh, Pa., died May 8, 1947. Mr. Evans was born October 14, 1892, in Spring Water, Wis., and received the degree of bachelor of science in 1914 and electrical engineer in 1926 from the University of Oklahoma. His association with the Westinghouse Company dated from 1914 when he entered the company's student course. He was assigned to the central station engineering department in 1916 as general engineer, being named engineer of transmission engineering in 1930 and manager of transmission engineering in 1931. He was titled central station engineer in 1935 and consulting transmission engineer in 1938. Mr. Evans contributed prolifically to the technical literature on stability in electric power systems and was associated in this work with the late C. L. Fortescue. With C. F. Wagner he wrote the first textbook on the subject of symmetrical components. In all, he wrote or collaborated on more than 40 books and technical papers dealing with the transmission of electric power. Mr. Evans also was credited with more than 75 patents in the United States. His AIEE activities included service on the committees on communications, power transmission and distribution (chairman, 1936–39), Standards, and the subcommittee on interconnection and stability factors.

Lester Seward Ready (A '15, M '32, F '36) consulting engineer, San Francisco, Calif., died April 9, 1947. Mr. Ready, who was born December 9, 1888, in Ventura, Calif., was graduated from the University of California in 1912 with the degree of bachelor of science in electrical engineering. After a brief period with the Pacific Gas and Electric Company, Oakland, Calif., he joined the California Railroad Commission in 1913 as assistant engineer in the gas and electric division, and in 1918 was named gas and electric engineer. He became chief engineer in 1923 and retired from that position to become president of the Key System Transit Company, Oakland, in 1926. In 1927 he opened a private consulting practice. At the time of his death he was consultant for the King's River Water Users Association and the Sacramento (Calif.) Municipal Utilities District. He was a former consultant for the Federal Power Commission and had been appointed to the California Water Resources Board by Governor Earl Warren. Mr. Ready served on the AIEE committee on legislation affecting the engineering profession from 1933 to 1940. He was a member of Eta Kappa Nu, Tau Beta Pi, Sigma Xi, and Phi Beta Kappa.

Thomas John Bostwick (A '18, M '26) consulting electrical engineer for the Aluminum Company of America, Pittsburgh, Pa., died May 8, 1947. Mr. Bostwick was born December 27, 1876, in Oswego, N. Y. After completing the student course at the Westinghouse Electric Corporation, East Pittsburgh, Pa., he became electrician in charge of operation of powerhouses for the Niagara Falls Power Company, Buffalo, N. Y., in 1897. He commenced his association with the Aluminum Company in 1900 as electrical engineer in charge of installation and operation of electric equipment in powerhouses, substations, and industrial plants. He was appointed assistant chief electrical engineer in 1912 and chief electrical engineer in 1924, retiring from that position in 1946. Under his guidance the Aluminum Company installed more than 500,000 kw of generating capacity and 800,000 kw of conversion equipment in its privately owned plants and approximately 1,500,000 kw of conversion capacity for Government-owned aluminum plants during World War II. Mr. Bostwick served on the AIEE committee on power generation in 1930 and 1931.

Edgar Clement Goodale (A '27, M '45) formerly electrical engineer, Bonneville Power Administration, Portland, Oreg., died April 28, 1947, in Riverhead, N. Y. Mr. Goodale was born in Riverhead, January 12, 1898, and was graduated from Cornell University with the degree of mechanical engineer in 1923. His first position was cadet engineer with the Syracuse (N. Y.) Lighting Company. After a brief period with the Stone and Webster Construction Company, Long Beach, Calif., and the Southern California Edison Company, Los Angeles, he became relay and meter inspector for the Puget Sound Power and Light Company, Tacoma and Olympia, Wash., in 1926. He joined the Bonneville Administration in 1940. Mr. Goodale, author of a number of technical articles, was awarded the North West District prize for best initial paper in 1930 and District best paper prize in 1938.

Ernest Frederick John Holcombe Hewlett (A '99, M '99) consulting engineer, Mansfield, Nottinghamshire, England, died January 22, 1947. Mr. Hewlett was born in Manchester, February 1, 1866, and attended the Manchester Technical School and Owens College. He entered the employ of the Edison Swan Electric Company Ltd., Manchester, in 1885 as an apprentice and was assistant manager when he left the company in 1891. Between 1891 and 1895 he was successively with Baerlein and Company, Manchester and Lisbon, Spain; Siemens Brothers, London; and the Hove Corporation. In 1895 he went to Australia as engineer and manager of the Rockhampton Electricity Works, Queensland, where he designed a complete lighting scheme for the town. Returning to England in 1901, he became the first borough electrical engineer for Mansfield. He retired in 1937 from that position.

Fred Dale Weber (A '09, M '30) formerly chief electrical engineer, Oregon Insurance Rating Bureau, Portland, died April 5, 1947, in Los Angeles, Calif. Mr. Weber was born in Rohnerville, Calif., July 28, 1880, and was graduated from the University of California. His first positions were with the Westinghouse Electric Corporation, and the Allis-Chalmers Manufacturing Company. In 1907 he joined the Oregon Rating Bureau and remained with it until his retirement a few years ago. Mr. Weber was a past president of the International Association of Electrical Inspectors and was secretary–treasurer of the Northwestern Section of the association until 1944. He was an electrical commissioner of the National Fire Protection Association for many years and served on the Oregon State Board of Engineers from 1919 to 1939. Mr. Weber also was a member of the North West Power Association.

Raymond S. Thomas (A '17) engineer, Western Light and Telephone Company, Kansas City, Kans., died April 18, 1947, Mr. Thomas was born in Blue Mound, Kans., June 6, 1890, and was graduated from the University of Kansas in 1915. He was employed by the Blackwell (Okla.) Smelters and the Bartlerville Zinc Company, Blackwell, before the first World War in which he served as a lieutenant in the Signal Corps. After the war he was engineer for the Water and Light Department of Blackwell and was associated for a time with the Benham Engineering Company, Kansas City, Mo. He joined the Arthur Muller Company, in 1924 and was resident engineer for the company in Fredonia, Kans., and in Kansas City. In 1934 he joined the Western Light and Telephone Company.

William Elmer (A '90, M '90, F '13) retired engineer, Pennsylvania Railroad Company, died May 6, 1947, in Rockledge, Fla. Mr. Elmer, who was born September 29, 1870, in Trenton, N. J., was graduated from Princeton University in 1894 with the degree of electrical engineer. He entered the employ of the Pennsylvania Railroad in 1896 as an apprentice and was made assistant engineer of motive power at Altoona, Pa., in 1903. He was appointed superintendent of motive power at Buffalo, N. Y., in 1911 subsequently becoming superintendent at Harrisburg, Pa., in 1917 and superintendent at Altoona in 1920. He was transferred to Philadelphia, Pa., as special engineer in 1926 and retired in 1935.

Charles C. Brown (A '22, F '30) electrical engineer, electrical distribution department, Wisconsin Electric Power Company, Milwaukee, died May 18, 1947. Mr. Brown was born March 13, 1887, and attended Highland Park College. After employment with the Illinois Northern Utility Company, Freeport, he joined the Milwaukee Electric Railway and Lighting Company, predecessor of the Wisconsin Company, in 1916 and was placed in charge of voltage regulations. He then was appointed starting and load engineer in 1922, assistant engineer in 1924, and electrical engineer in 1929.

Henry Raymond McHugh (A '45) inspector, electric power cable, Kennecott Wire and Cable Company, Phillipsdale, R. I., died April 19, 1947. Born in Phillipsdale, February 18, 1902, Mr. McHugh attended Brown University. He joined the American Electrical Works, which later became the Kennecott Company, in 1920 as an electrician. He was appointed assistant in the laboratory in 1925 and cable inspector in 1930.

Frederick William Herbert Wheadon (A '17) until recently managing director and chief engineer of the Adelaide (South Australia) Electric Supply Company, Ltd., died recently. Mr. Wheadon was born December 15, 1872, in Ilminster, Somerset, England, and commenced his career as assistant operating engineer for the City of London Electric Lighting Company, from 1893 to 1898. He was supervising engineer with the firm of Babcock and Wilcox, Ltd., London, before going to Australia in 1899 as chief engineer and manager for the Adelaide Electric Company. He was appointed managing director in 1923. Mr. Wheadon was a member of the Institution of Electrical Engineers and a past president of the Institute of Engineers of South Australia. He represented the Standards Association of Australia at the International High-Voltage Conference in Paris, France, in 1925.

William Marshall Reid (A '20) district meter inspector, operating department, Hydro-Electric Power Commission of Ontario, Toronto, Canada, died recently. Born December 14, 1894, in Vinemount, Ontario, Mr. Reid was graduated from the University of Toronto in 1919. Later that year he joined the Hydro-Electric Commission as meter inspector and was named district meter inspector in 1923.

MEMBERSHIP • •

Recommended for Transfer

The board of examiners, at its meeting of May 15, 1947 recommended the following members for transfer to the grade of membership indicated. Any objection to these transfers should be filed at once with the secretary of the Institute.

To Grade of Fellow

Allen, J. E., chief of tests, Pennsylvania Water & Power Co., Baltimore, Md.
Scudder, F. J., director of switching development, Bell Tel. Labs. Inc.

2 to grade of Fellow

To Grade of Member

Allen, E., general service engineer, Electric Power Board, Chattanooga, Tenn.
Arnaud, F. J., elec. engr., Allis-Chalmers Mfg. Co., West Allis, Wis.
Babcock, D. L., head engg. dept., Key System, Oakland, Calif.
Barr, M. K., chief engineer, Copper Wire Engg. Assn., Washington, D. C.
Beamer, S., elec. engr., Clyde E. Bentley, C.E., San Francisco, Calif.
Benedict, F. R., mgr. industry engg. dept., Westinghouse Elec. Corp., E. Pittsburgh, Pa.
Burian, K., elec. engr., G. M. Laboratories, Inc., Chicago, Ill.
Carter, E. F., vice pres. in charge of engg., Sylvania Elec. Products Inc., New York, N. Y.
Claridge, R. E., vice pres. of Control Corp. Ltd., New Toronto, Ont. Can.
Colby, R. L., Jr., engineer, Research Field Test Group, Boeing Aircraft Co., Seattle, Wash.
Dosey, H. W., elec. engr., Republic Steel Corp., Cleveland, Ohio.
Esval, O. E., director of aeronautical engg., Sperry Gyroscope Co. Inc., Great Neck, N. Y.
Fahey, J. D., asst. power co-ordinator, Univ. of Calif. Radiation Lab., Berkeley, Calif.
Feige, W. C., Jr., consulting engineer, Baltimore, Md.
Giegerich, B. V., development engineer, General Elec. Co., Pittsfield, Mass.
Gray, J. M., chief elec. engr., Maryland Drydock Co., Baltimore, Md.
Gray, W. T., III, research physicist, Corning Glass Works, Corning, N. Y.
Haberland, E. R., elec. engr., Naval Ordnance Lab., White Oak, Md.
Hart, J. V., chief inspector, Brown Instrument Co., Phila., Pa.
Holcomb, J. E., elec. engr., General Elec. Co., Pittsfield, Mass.
Hornberger, R. G., office engr., Sverdrup & Parcel, San Francisco, Calif.
Johnson, L. W., industrial heating specialist, General Elec. Co., Phila., Pa.
Kohler, A. J., engineer, Federal Power Comm., Washington, D. C.
Kroeger, E., elec. engr., Ross Electric Co., Philadelphia,Pa.
Kulikowski, E. F. head, systems utilization sec., Naval Research Lab., Washington, D. C.
McKeever, J. L., engineer-in-charge, Industrial Central Sta. Engg. Div., Canadian Gen. Elec. Co., Ltd., Peterborough, Ont., Can.
McNall, J. W., research section engr., Westinghouse Lamp Div., Bloomfield, N. J.
Mohler, D. D., field construction engr., Rural Electrification Adm., Iowa City, Ia.
Neidig, R. E., elec. engr., Metropolitan Edison Co., Reading, Pa.
Newton, J. C. project engr., Sperry Gyroscope Co. Inc., Garden City, N. Y.
Ostergren, C. N., depreciation & price survey engr., American Tel & Tel Co., New York, N. Y.
Sims, J. B., supt. public works, City Hall, Grand Haven, Mich.
Stratton, G. F., treas., Armature Winding Co., Charlotte, N. C.
Stratton, W. L., pres., Armature Winding Co., Charlotte, N. C.
Thomson, M., consulting welding engr., General Elec. Co., West Lynn, Mass.
Varma, R. D., pump engr., Tube Well Circle, Meerut, India.
Veterneck, J. S., asst. elec. engr., Brown Engg. Co., Des Moines, Ia.
Votaw, R. W., engr., General Elec. Co., Schenectady, N. Y.
Wagner, C. H., Jr., asst. dist. engr., American Gas & Elec. Ser. Corp., New York, N. Y.
Weyl, C., prof. elec. engg., Moore School of Elec. Engg., Univ. of Penn., Phila., Pa.
Whitehouse, A. B., supt., dist. elec. dept., Lynn Gas & Elec. Co., Lynn, Mass.
Wilson, A. P., chief elec. engr., Aeromotive Engg. Co., Niles, Mich.
Work, W. W., asst. to div. engr., General Elec. Co., Lynn, Mass.

43 to grade of Member

Applications for Election

Applications have been received at headquarters from the following candidates for election to membership in the Institute. Any member objecting to the election of any of these candidates should so inform the secretary before July 21, 1947, or September 21, 1947, if the applicant resides outside of the United States, Canada, or Mexico.

To Grade of Fellow

Allen, O. F. (re-election) Paper Plastic Products Co., New York, N. Y.
Diamond, H., Natl. Bureau of Standards, Washington, D. C.
Suffern, M. G., Naval Research Lab., Washington, D. C.

3 to grade of Fellow

To Grade of Member

Abele, R. J., Burroughs Adding Machine Co., Detroit, Mich.
Ansel, Murry, L., J. Livingston & Co., Detroit, Mich.
Bartel, A. O., Perfex Corp., Milwaukee, Wis.
Boyce, H. J., Polar Engineering Co., Danbury, Conn.
Brown, R. L., Smithey & Boynton, Roanoke, Va.
Burda, E. J., General Elec. Co., Schenectady, N. Y.
Carrell, E. W., Carrell Elec. Motor Shop, Fullerton, Calif.
Christian, L. C., Jr., Gulf States Utilities Co., Lake Charles, La.
Ciganek, L., Technical University, Bratislava, Czechoslovakia.
Code, J. A., Jr., 332 S. Michigan Ave., Detroit, Mich.
Cotterill, J. R., General Elec. Co., Witton Birmingham, England.
Craig, A. P., Canadian Westinghouse Co. Ltd., Hamilton, Ont., Canada.
Cruickshank, J. P., Appalachian Elec. Pr. Co., Roanoke, Va.
Cumming, L. G., Inst. of Radio Engineers, New York, N. Y.
Degni, L. F., N. Y. Naval Shipyard, Brooklyn, N. Y.
Dewey, D. W., Cincinnati Gas & Elec. Co., Cincinnati, Ohio.
Dunbar, G. M., Elder Dempster Lines, Ltd., Liverpool, England.
Elkins, C. C., Jr., Texas Trade School, Dallas, Tex.
Goedhals, G., E.R.P.M.G.M., Ltd., South Rand, South Africa.
Goodwin, A. E., General Elec. Co., Schenectady, N. Y.
Hastings, D. J., Electricity Supply Comm. of South Africa, Johannesburg, South Africa.
Hoper, C. H., Bureau of Reclamation, Grand Island, Nebr.
Hyltin, M. G., Lower Colorado River Authority, San Marcos, Tex.
Krebs, W. W., Appalachian Elec. Pr. Co., Roanoke, Va.
Krieg, E. H., American Gas & Elec. Service Corp., New York, N. Y.
Lawrence, H. J., 335 W. North Ave., Milwaukee, Wis.
Leblanc, J., Rural Electrification Bureau, Quebec, P. Q., Canada.
McClenahen, J. F., General Elec. Co., E. Cleveland, Ohio.
McGuire, C. H., Bell Tel. Co. of Canada, Montreal, Que., Canada.
McManus, C. B., Georgia Pr. Co., Atlanta, Ga.
Milne, E. R. A., Everett Edgcumbe & Co., Ltd., London, England.
Nichols, Eldon, American Tel. & Tel. Co., New York, N. Y.
Pollard, T. R., Canterbury University College, Christchurch, N. Z.
Preston, R. V., Westinghouse Elec. Corp., Roanoke, Va.
Russell, R. F., Norfolk Naval Shipyard, Portsmouth, Va.
Seay, G. L., 128 West Kirk Ave., W., Roanoke, Va.
Sittel, V. J., Stanolind Pipe Line Co., Tulsa, Okla.
Smith, D. D., N.A.C.A., Langley Field, Va.
Waddington, J. S., Phillips Elec. Works, Ltd., Brockville, Ont., Canada.
Walsh, W. F., Central Hudson Gas & Elec. Co., Poughkeepsie, N. Y.
Whistler, C. H., S. F. Chamberlain Co., New York, N. Y.
Whitmore, J. B., Appalachian Elec. Pr. Co., Roanoke, Va.
Whitney, G. S., N. Y. State Agric. & Tech. Institute, Alfred, N. Y.
Wolff, H. H., 35 Hamilton Place, New York, N. Y.
Wrege, E. C., N.A.C.A., Cleveland Airport, Cleveland, Ohio

45 to grade of Member

To Grade of Associate

United States, Canada, and Mexico

1. North Eastern

Avery, E. S., General Elec. Co., Schenectady, N. Y.
Bennett, J. R., N. Y. State Elec. & Gas Corp., Elmira, N. Y.
Blanco, B. C., General Elec. Co., Schenectady, N. Y.
Bossuyt, E. F., General Elec. Co., Schenectady, N. Y.
Cheney, R. E., IBM Corp., Endicott, N. Y.
Chung, S., Mass. Inst. of Tech., Cambridge, Mass.
Dallas, J., New York, New Haven & Hartford RR, New Haven, Conn.
Hall, H. D., Lab. for Electronics, Inc., Boston, Mass.
Kohler, C. G., Western Elec. Co., West Haven, Conn.
Regan, M. J., Westinghouse Motor Div., Buffalo, N. Y.
Robb, E. J., Harvard Univ., Boston, Mass.
Sours, D. T., Watson Laboratories, Cambridge, Mass.
Uses, E. P., General Elec. Co., Bridgeport, Conn.

2. Middle Eastern

Boyce, R. M., Crise Mfg. Co., Columbus, Ohio.
De Mott, D. H., Curtiss-Wright Corp., Columbus, Ohio.
Fegley, K. A., Univ. of Pennsylvania, Philadelphia, Pa.
Feik, R. L., Air Materiél Command, Wright Field, Dayton, Ohio.
Gubanc, R. D., Federal Machine & Welder Co., Warren, Ohio.
Herbine, E. F., Spicer Mfg. Corp., Pottstown, Pa.
Hoban, E. J., Elec. Controller & Mfg. Co., Cleveland, Ohio.
Hooffstetter, W. B., Columbus & Southern Ohio Elec. Co., Columbus, Ohio.
Hower, G. C., Westinghouse Elec. Corp., Lima, Ohio.
Hunt, W. E., General Elec. Co., Philadelphia, Pa.
McElvarr, L. J., General Elec. Co., Philadelphia, Pa.
Patterson, G. V., Ohio Pr. Co., Canton, Ohio.
Pringle, D. O. (re-election) Ohio Pr. Co., Canton, Ohio.
Reimer, L. G., Westinghouse Elec. Corp., East Pittsburgh, Pa.
Richman, M. A., Naval Research Lab., Washington, D. C.
Scott, C. L., Consolidated Gas Elec. Lt. & Pr. Co. Baltimore, Md.
Slief, L. O., Duquesne Light Co., Pittsburgh, Pa.
Smith, G. H., Jr., Fenn College, Cleveland, Ohio.
Stokes, J. W., Stokes Engineering & Supply Co., Easton, Pa.
Woody, E. W., Foreman, Appalachian Elec. Power Co., Charleston, West Va.

3. New York City

Gately, W. J., American Cyanamid Co., New York, N. Y.
Joehlin, N. C., Federal Telephone & Radio Corp., Clifton, N. J.
Lawrence, P. J., Wright Aeronautical Corp., Woodridge, N. J.
Pinter, E. E., J. S. Hamel Engr., New York, N. Y.
Press, M., Columbia Univ., New York, N. Y.
Smith, A. K., Simplex Wire & Cable Co., New York, N. Y.
Winckler, R. H. (re-election) Bell Tel. Labs., Murray Hill, N. J.

4. Southern

Adams, C. G., Alabama Pr. Co., Birmingham, Ala.
Adkins, B. H., Westinghouse Elec. Corp., Roanoke, Va.
Armistead, R. A., Appalachian Elec. Pr. Co., Roanoke, Va.
Arnett, W., Alabama Pr. Co., Birmingham, Ala.
Bailey, P. L., Appalachian Elec. Pr. Co., Roanoke, Va.
Baxter, L. J., T.V.A., Jackson, Tenn.
Creswell, F. L., Southwestern Gas & Elec. Co., Shreveport, La.
Fishburne, F. J., South Carolina Pr. Co., Charleston, S. C.
Gautschi, T. F., Smith Construction Co., Nashville, Tenn.
Hatfield, C. D., T.V.A., Norris, Tenn.
Hoy, H. C., Jr., Route 13, Black Oak Ridge, Knoxville, Tenn.
Johnson, L. E., R. H. Bouligny, Inc., Charlotte, N. C.
Legare, T. C. R., South Carolina Pr. Co., Charleston, S. C.
Mattern, E. K., Mattern & Mattern, Roanoke, Va.
McClannan, O. Y., Jr., Naval Air Sta., Norfolk, Va.
Morgan, L. P., Southern Bell Tel. & Tel. Co., Charleston, S. C.
Munday, E. L., Jr., Appalachian Elec. Pr. Co., Roanoke, Va.
Nash, R. V., Westinghouse Elec. Supply Co., Roanoke, Va.
Neal, A. R., Jr., Appalachian Elec. Pr. Co., Roanoke, Va.
Pharis, J. H., Jr., General Elec. Co., Roanoke, Va.
Pincus, A. S., Tulane Univ., New Orleans, La.
Rankin, E. C., Appalachian Elec. Pr. Co., Roanoke, Va.
Scott, J. M., Jr. (re-election), Univ. of Florida, Gainesville, Fla.
Southern, A. L., Univ. of Tenn., Knoxville, Tenn.
Stone, B. T., Appalachian Elec. Pr. Co., Roanoke, Va.
Tillett, A. B., Appalachian Elec. Pr. Co., Roanoke, Va.
Tillman, J. D., Jr., Univ. of Tenn., Knoxville, Tenn.
Vreeland, F. S., Barber-McMurry, Knoxville, Tenn.
Youngman, R. A., Appalachian Elec. Pr. Co., Roanoke, Va.

5. Great Lakes

Balliet, R. S., Cutler-Hammer, Inc., Milwaukee, Wis.
Boess, M. R., Jr., Delta Star Elec. Co., Chicago, Ill.
Butler, R. M., Univ. of Michigan, Ann Arbor, Mich.
Diebolt, H. J., U. S. Rubber Co., Detroit, Mich.
Egbert, P. R., Univ. of Illinois, Urbana, Ill.
Faust, S. R., Jr., United Air Lines, Inc., Chicago, Ill.
Franze, R. D., Central Illinois Elec. & Gas Co., Rockford, Ill.
Kemppainen, A. O., Lightning and Transients Research Inst., Minneapolis, Minn.
Mandzyn, M., American Television, Inc., Chicago, Ill.
Urban, H. J., Cline Elec. Mfg. Co., Chicago, Ill.

6. North Central

Johnson, J. H., Univ. of Wyoming, Laramie, Wyo.
Lewis, E. F., Omaha Public Pr. Dist., Omaha, Nebr.
Varney, E. C., U. S. Bureau of Reclamation, Denver, Colo.

7. South West

Cole, W. A., Kennecott Copper Corp., Santa Rita, New Mex.
Eubank, L. C., Texas Pr. & Lt. Co., Dallas, Tex.
Key, C. B., Electron Repair Shop, Mexico, D. F. Mex.
Klamm, C. F., Jr., Washington Univ., St. Louis, Mo.
Mickle, E. R., Univ. of Texas, Austin, Tex.
O'Connell, J. T., Southwestern Bell Tel. Co., Dallas, Tex.
Sandlin, J. L., Priester Supply Co., Dallas, Tex.
Smith, H., El Paso Elec. Co., La Cruces, New Mex.
Watts, R. P., Southwestern Pub. Serv. Co., Borger, Tex.

8. Pacific

Bowman, S., Pacific Gas & Elec. Co., San Jose, Calif.
Burkhead, M. D., Pacific Gas & Elec. Co., San Jose, Calif.
Casey, V. J., Pacific Tel. & Tel. Co., Los Angeles, Calif.
Coffey, C. T., U. S. Bureau of Reclamation, Sacramento, Calif.
Forrest, L. W., Cole Elec. Co., Culver City, Calif.
Gardner, P. R., Southern California Edison Co., Los Angeles, Calif.
Hawley, D. H., Southern California Edison Co., Los Angeles, Calif.
Hendricks, P. P., Southern California Edison Co., Los Angeles, Calif.
Hook, F. M., Pacific Gas & Elec. Co., Oakland, Calif.
Lindberg, C. L., Central Ariz. Lt. & Pr. Co., Phoenix, Ariz.
Lytle, J. H. R., U. S. Naval Shipyard, Terminal Island, San Pedro, Calif.
Marden, J. R., Pacific Tel. & Tel. Co., San Francisco, Calif.
Marker, H. R., Cole Electric Co., Culver City, Calif.
McNulty, J. W., Pacific Tel. & Tel. Co., San Francisco, Calif.
Meyer, H. P. (re-election), Salt River Valley Water Users Assn., Tempe, Ariz.
Meyers, R. Y., General Elec. Co., San Diego, Calif.
Myers, W. J., Allis-Chalmers Mfg. Co., San Diego, Calif.
Newman, J. E., Leach Relay Co., Los Angeles, Calif.
O'Halloran, J. F., Univ. of California Radiation Lab., Berkeley, Calif.
Purtill, H. L., Granite Rock Co., Watsonville, Calif.
Sampson, F. K., Kistner, Curtis & Wright, Los Angeles, Calif.
Schoenenberger, E. B., Pacific Gas & Elec. Co., San Jose, Calif.
Schroder, H. L., 2828 E. Cajon Blvd., San Diego, Calif.
Waight, V. H., California Div. of Highways, San Francisco, Calif.
Wendt, E. H., Dept. of Water & Power, Los Angeles, Calif.
Whitnell, J. D., Central Ariz. Lt. & Pr. Co., Phoenix, Ariz.
Yelton, P. H. (re-election), California Power Co., Riverside, Calif.

9. North West

Ashla, N. (re-election), Portland Dist. Engr. Office, Portland, Oreg.
Maxwell, A. A., General Elec. Co., Richland, Wash.
Otto, A. A., General Elec. Co., Hillsboro, Oreg.
Spring, B. H., 226 North 32 Street, Corvallis, Oreg.

10. Canada

Cathcart, G. B., Canadian General Elec. Co., Ltd, Ottawa, Ont., Canada.
Hipwell, F. O., Alliance Tool & Motor Co., Etobicoke, Toronto, Ont., Canada.
Nachfolger, N., Northern Elec. Co. Ltd., Montreal, Quebec, Canada.
Scarlett, F. M., Packard Elec. Co., Ltd., Montreal, Quebec, Canada.

Elsewhere

Gopaliengar, M. K., Central Technical Power Board, Cleremont, The Mall, Silma, India.
Mainwaring, A. H., R.A.F., Bushbury, Wolverhampton, England.
Saha, R. K., British Thompson Houston Co., Rugby, England.
Tora, J. L., Narvaez, 14, Madrid, Spain.
Venner, M., Metropolitan-Vickers Elec. Co. Ltd., Trafford Park, Manchester, England.

Total to grade of Associate
United States, Canada and Mexico, 126
Elsewhere, 5

Report of the Board of Directors

THE BOARD OF DIRECTORS of the American Institute of Electrical Engineers presents herewith to the membership its 63rd annual report, for the fiscal year ending April 30, 1947. It includes a general balance sheet and other statements showing the financial condition of the Institute at the close of the fiscal year and a brief summary of the principal activities of the Institute during the year, more detailed information having been published from month to month in *ELECTRICAL ENGINEERING.*

BOARD OF DIRECTORS' MEETINGS

Six meetings of the board of directors were held during the year, three in New York, N. Y., one in Asheville, N. C., one in Detroit, Mich., and one in Worcester, Mass.

Information regarding many of the more important activities of the Institute which have been under consideration by the board of directors and AIEE committees is published each month in the section of *ELECTRICAL ENGINEERING* devoted to Institute activities.

PLACES VISITED BY PRESIDENT HOUSLEY

Alabama

Muscle Shoals Section, Florence

Arizona

Arizona Section, Phoenix

Arkansas

Little Rock Subsection of Memphis (Tenn.) Section

California

Los Angeles Section, San Diego Section
San Francisco Section
California Institute of Technology Branch, Pasadena
University of California Branch, Berkeley

Canada

Vancouver Section
Summer general meeting, Montreal, Quebec

Colorado

Denver Section

District of Columbia

Washington Section

Illinois

Rock River Valley Subsection of Madison (Wis.) Section, Rockford

Indiana

Great Lakes District meeting, Indianapolis

Iowa

Iowa Section, Ames
Iowa State College Branch, Ames

Kentucky

Louisville Section; University of Louisville Branch
University of Kentucky Branch, Lexington

Louisiana

New Orleans Section, Lake Charles Subsection
Shreveport Subsection

Massachusetts

Boston Section
North Eastern District meeting, Worcester

Mexico

Mexico Section, Mexico, Federal District

Minnesota

Minnesota Section, Minneapolis
Arrowhead Subsection, Duluth

Mississippi

Mississippi State College Branch, State College

Missouri

St. Louis Section

Montana

Montana Section, Butte

Nebraska

Nebraska Section, Omaha
University of Nebraska Branch, Lincoln

New York

New York Section; winter meeting, New York, N. Y.

North Carolina

North Carolina Section, Durham
Duke University Branch, Durham

Ohio

Cincinnati Section, Cleveland Section
Dayton Section, Mansfield Section
Akron Section, Columbus Section

Oklahoma

Oklahoma City Section
Tulsa Section

Oregon

Portland Section

Pennsylvania

Philadelphia Section
Pittsburgh Section
Sharon Section

South Carolina

South Carolina Section, Columbia

Tennessee

East Tennessee Section, Athens, Chattanooga
Memphis Section

Texas

Beaumont Section, Houston Section
New Mexico–West Texas Section, El Paso
North Texas Section, Dallas

Utah

Utah Section, Salt Lake City

Washington

Spokane Section
Pacific Coast meeting, Seattle

West Virginia

West Virginia Section, Charleston

ANNUAL MEETING

The annual business meeting of the Institute was held June 26, 1946, in Detroit, Mich. The annual report of the board of directors for the fiscal year which ended April 30, 1946, was presented in abstract by Secretary H. H. Henline. The Institute's financial situation was summarized by Treasurer W. I. Slichter. The report of the committee of tellers on the election of officers for the year which commenced August 1, 1946, was presented, and President-Elect J. Elmer Housley responded to his introduction with a brief address. National prizes for papers were presented.

The AIEE Lamme Medal for 1945 was presented to David C. Prince, vice-president of the General Electric Company, and a past president of the Institute. An address in recognition of the 100th anniversary of the birth of George Westinghouse was presented by J. K. B. Hare, vice-president of the Westinghouse Electric Corporation. The president's address by Doctor William E. Wickenden concluded the meeting.

NATIONAL MEETINGS

Three national meetings were held during the year, and a brief report on each follows.

Summer Meeting. The 61st annual summer meeting was held in Detroit, June 24–28, 1946, with a registration of 1,351. The program included 19 technical sessions, 7 technical conferences, 8 administrative conferences, and 23 committee meetings, in addition to the afore-mentioned annual business meeting. There were entertainment events, inspection trips, golf tournaments, a president's reception, and a dinner dance.

Pacific Coast Meeting. The 33rd Pacific Coast meeting was held in Seattle, Wash., August 27–30, 1946, with a registration of 562, which was a record for Pacific Coast meetings. Six technical sessions, one student technical session, and a conference on organization of the engineering profession were held. The program also included inspection trips, president's reception, banquet, theater party, women's activities, and a golf tournament.

Winter Meeting. The 35th winter meeting was held in New York, N. Y., January 27–31, 1947, with a registration of 3,567, an all-time record. The program included 29 technical sessions, 10 technical conferences, 2 administrative conferences, and 3 general sessions at which the Edison, Hoover, and John Fritz Medals were presented to Doctors Lee de Forest, Vannevar Bush, and Lewis W. Chubb, respectively.

Other events of the meeting were a smoker, inspection trips, events for women, and a cocktail party by the Aluminum Company of America for President Housley.

DISTRICT MEETINGS

Great Lakes District Meeting. This meeting was held in Indianapolis, Ind., October 9–11, 1946, with a registration of 298. Conferences were held on electric machinery, electronics, power transmission and distribution, industrial power applications, communication, industrial control, basic sciences, and organization of the engineering profession. At the banquet, Doctor Frank H. Spedding, of Iowa State College, gave an address on "Nature and Implications of Atomic Energy." There were inspection trips as well as a number of women's activities.

North Eastern District Meeting. Held in Worcester, Mass., April 23-25, 1947, with a registration of 828, this was the largest District meeting held since 1927. The program included 8 technical sessions, 2 student technical sessions, a general session, inspection trips, women's events, smoker, and banquet. At the banquet, Doctor Samuel Van Valkenburg, director, Graduate School of Geography, Clark University, gave an address on "The European Puzzle."

Southern District Meeting. The sixth Southern District meeting was held in Asheville, N. C., May 14–16, 1946, with a registration of 373, which was the second highest in the history of the meeting. One of the three technical sessions was devoted to a symposium on electric power in the textile industry. A conference on student activities and a student paper session also were included in the program, and inspection trips were made to near-by plants. Commander J. F. Hellweg, United States Navy (retired), addressed an evening session and AIEE Past President C. A. Powel described conditions as he had seen them in Germany during a 9-month tour of duty as chief of the electrical and radio branch of the Allied Control Commission.

COMMITTEE ON COLLECTIVE BARGAINING AND RELATED MATTERS

During the year, this committee has continued its work on the preparation of "A Manual on Collective Bargaining for Professional Employees." The first edition of this manual, which deals with the National Labor Relations Act, and an analysis of proposals from various sources for modifying the act, has been completed and should be available to members before the end of April 1947. Through co-operation with the Committee on the Economic Status of the Engineer of Engineers Joint Council, the publication of the manual is being sponsored jointly by six of the major professional engineering societies.

Through the same channel, the committee on collective bargaining and related matters has attempted to co-operate with other professional engineering societies in the establishment of a policy and a procedure covering labor legislation. The committee endorsed the policy and procedure recommended by the Committee on the Economic Status of the Engineer, and this endorsement was followed by approval by the AIEE board of directors and by Engineers Joint Council. In December 1946, Engineers Joint Council approved another policy and procedure not endorsed by the committee on collective bargaining and related matters.

The committee recommended to the AIEE board of directors that a comprehensive questionnaire be sent to AIEE members for the purpose of ascertaining their opinions regarding attempts at modification of the National Labor Relations Act in the interest of professional employees. This recommendation was approved at the January 1947, meeting of the board of directors, but before a comprehensive questionnaire could be prepared and distributed, a letter, dated February 7, 1947, and an incomplete questionnaire, dated March 17, 1947, were sent to the membership by the president of the Institute. The committee had nothing to do with the preparation of this letter, or of this questionnaire, and did not approve them or the procedure followed. The chairman of the committee on collective bargaining and related matters has requested that the committee be relieved of any responsibility for matters having to do with labor legislation, or alternatively, that his resignation be accepted.

General Committees

SECTIONS COMMITTEE

1. *Section Programs.* The Sections generally have been continuing the policy of following a program of expanding their activities to meet the increased scope and growing demands of the electrical engineering profession and to provide for the diversification of interest of the Section members. Increased attention is being given to student activities, social activities, fellowship at meetings, inspection trips, and the broader subject of civic responsibilities of engineers. Section officers generally are becoming more conscious of the importance of balanced Section operation, which provides activities to retain the older members as well as attract new members. In giving more time to creative work and the co-ordination of the activities of their Sections, many chairmen have followed the suggestion of delegating to committees much of the operating work of running the Section. The resulting increase in operating committees in many Sections has provided the opportunity for more members to work actively for the Section, which in turn has created additional interest.

2. *Sections Committee Organization.* Because of the volume of the Sections committee work, the committee continued to operate as two groups. The planning group, consisting of six members, initiates and develops all plans of the committee. The promotional group, consisting of ten members located geographically on a District basis, handles much of the promotional work individually with the Sections and Districts. Most of the material used by the promotional group is sent to each member, who in turn supplements it with his personal knowledge of local conditions before contacting the Sections in his District. Close contact is maintained between the promotional group member and the vice-president of the District.

3. *Conferences Held at Summer Meeting.* During the summer meeting at Detroit, the following conferences were held:

June 24, 1946—Conference on Section Operation and Management for Section Delegates. Three separate parallel conferences were held. One for the larger Sections, one for the intermediate Sections, and one for the smaller Sections. These conferences were conducted in an informal manner according to a prearranged program which covered many of the important items in connection with the operation of the Sections.

June 25, 1946—Conference of Officers, Delegates, and Members. This was the annual meeting of the delegates. The meeting was addressed by Institute president, Doctor Wickenden, whose topic was "Observations on Institute Activities." The program included a report on District and Section activities by Secretary Henline, remarks by Presidential Nominee Housley, and the report of the Sections committee. The report on the improved AIEE publications services was made by G. Ross Henninger, AIEE editor. Reports also were made on membership activity, Section finance, educational courses, and Section history.

June 26, 1946—Conference on Section Activities in Connection With Local Councils of Engineering and Technical Societies. In this conference the organization and operation of local engineering councils was presented and discussed, with particular emphasis on the part the AIEE Sections have taken in this work. The attendance at this meeting was an indication of the interest in this subject.

June 27, 1946—Conference on Section–Branch Co-operation. This was a joint activity with the committee on Student Branches. In this conference a plan of Section–Branch co-operation was presented and discussed. Many examples of this activity were discussed by the Section delegates. The discussion at this meeting indicated the importance of this activity to the Institute.

4. *Discussion of Section Operation and Management at District Meetings.* In accordance with recommendations made by the delegates at the Sections committee meeting, January 22, 1946, the Sections committee encouraged all vice-presidents to devote a portion of their District executive committee meetings to a discussion of Section operation and management. These discussions were held at most of the District executive committee meetings and served to supplement the regular delegates' meetings which were held at Detroit.

5. *Technical Groups.* The development of technical groups within the Sections continued to be one of the most important activities of the Sections committee. Copies of the folder, "Technical Groups," were distributed to each Section chairman at the beginning of the year. The promotional group supplied individual Sections with several reports of examples of successful operation of these groups. There were 105 of these groups in operation as compared with 74 in operation a year ago. Reports received from the Sections indicate many other groups are in process of being formed.

On January 5, 1947, a letter was sent to all Sections encouraging the formation of basic science technical groups as an additional activity. During this year the Sections committee started a long range plan for co-operation between the technical groups in the Sections and the technical committees of the Institute. It was pointed out that this co-operation should be a 2-way activity, and, when working properly, desirable information would be flowing from the Section and technical groups to the technical committees of the Institute, as well as from the technical committees to the Sections. A 3-point program on this activity for the Sections to follow was contained in a letter dated November 8, 1946, to all Section chairmen. A letter dated November 7, 1946, to the chairmen of all Institute technical committees covers suggestions for obtaining information for technical groups in the Sections. These initial letters were followed later in the year by other letters giving practical suggestions and practical examples of the operation of this co-operative plan.

6. *Subsections.* Subsection activity was continued by the committee throughout the year. A copy of the folder, "Subsections," was sent to each Section chairman at the beginning of the year. The promotional group of the Sections committee has forwarded examples of successful operation of Subsections to the individual Sections in their Districts. There are now 35 Subsections in operation, as compared with 25 Subsections in operation at the end of the previous year. Many opportunities still exist for members in the remote areas of the Section territory to participate in Section activities through the development of Sub-

sections in these areas. The promotional group of the Sections committee conducted a survey of the possibilities of Subsections in each of their Districts. As a result of this survey, many additional locations for Subsections are being considered by the Sections.

7. *Local Councils of Engineering and Technical Societies.* During the year, the Sections committee has continued the activity of encouraging AIEE Sections to assist in organizing councils and to be active in these councils where they already are organized. There are now 45 of these councils in active operation. During the year the Sections committee sent considerable information to five AIEE Sections which are active in forming new councils in their areas.

8. *Section Finance.* During the year, the Sections committee observed the operation of the revised system of allotments to the Sections. No new recommendations were made this year.

9. *Student Activities.* Section–Branch activity in co-operation with the committee on Student Branches was continued throughout the year. Copies of the plan of Section–Branch co-operation were distributed to all Section chairmen during the year. It was pointed out that co-operation with the Branches is a very important activity and that the Sections can assist materially in this activity by helping the Student Branches to develop the interest of all electrical engineering students.

10. *Educational Courses.* The plan of encouraging the Sections to organize educational courses for their members and others was continued during the year. This is a joint activity with the committee on education. On October 30, 1946, a letter was sent to all Section chairmen calling attention to the possibility of these educational courses and enclosing a case example of the experience of the Philadelphia Section in conducting educational courses. Later in the year, information on the courses conducted by the New York Section was forwarded to most Sections by the members of the promotional group of the Sections committee.

11. *Changes in Section Territory.* The island of Puerto Rico was added to the territory of the New York Section. The Territory of Hawaii was made a part of District 8 and of the territory of the San Francisco Section.

12. *Section History.* The activity of encouraging Sections to write a Section history was continued throughout the year. As a result of this activity, many Sections have appointed a history committee to proceed with this work. A letter has been sent to all Sections enclosing a suggested outline for a Section history.

13. *Prize Paper Activity.* Many Sections conduct prize paper contests, and the Sections committee has been endeavoring to stimulate this activity by having Section prize paper awards given official recognition by the Institute. This activity is being considered by a special Institute committee for the revision of the prize paper rules, and as a result of the Sections committee activity in connection with the work of the special committee, it is expected that the proposed revision of the Institute prize paper rules will contain official recognition for Sections awards.

Table I. Section and Branch Statistics

	For Fiscal Year Ending April 30					
	1942	1943	1944	1945	1946	1947
Sections						
Number of Sections	72	73	73	73	75	75
Number of meetings held	647	598	738	884	1,210	1,333
Total attendance	78,254	66,111	83,120	96,346	113,531	155,649
Branches						
Number of Branches	124	125	125	125	125	126
Number of meetings held	946	942	755	547	716	1,018
Total attendance	37,785	38,227	24,768	17,132	22,844	40,669

14. *Safety Activity.* In co-operation with the Institute committee on safety, the Sections committee sent a letter, dated September 17, 1946, to all Sections concerning the importance of including the subject of safety in their programs. An appendix to this letter gave many examples of how this activity could be conducted by the Sections. This safety activity is being conducted from the standpoint of the engineer and covers the safety angle in the design, construction, operation, and maintenance of equipment, rather than from the safety-first approach.

15. *Edison Centennial Meetings.* As a result of the board of directors of the Institute endorsing the idea of co-operation by AIEE Sections with the Edison Centennial Committee in appropriate local observances of the commemoration of the centennial of the birth of Thomas A. Edison, a letter dated September 4, 1946, was sent to all Sections outlining a suggested program for Section and Subsection meetings on the centennial date, February 11, 1947. In compliance with this suggestion, many Sections and Subsections held special meetings on February 11, and other Sections included the observance of this centennial in connection with their regular meetings.

16. *Industrial Meetings.* As a result of the address of President Housley, a letter of October 11, 1946, was sent to all Sections suggesting that they hold meetings on an industrial subject in electrical engineering in the smaller industrial centers in their areas. An appendix to this letter contained several suggestions for conducting these meetings. It also was suggested that these meetings be built around the publication, "Electric Power Distribution for Industrial Plants," which was developed by the Institute committee on industrial power applications. The Sections engaging in this activity found these meetings to be a very profitable Institute activity.

17. *Delegates' Meetings to be Held at the Summer General Meeting, Montreal.* The Sections committee has prepared a comprehensive program for the Institute officers, Section delegates, and members at the summer general meeting. Three parallel conferences on Section operation and management will be conducted on June 9, with the delegates divided into groups representing the larger, intermediate, and smaller Sections. These conferences will be held on a strictly informal basis. The conference of officers, delegates, and members will be held June 10, at which the more formal program of reports will be presented. On June 11 a special conference on technical group activities in the Sections will be held. At this conference, the experiences in operating technical groups will be discussed, and the co-operation between the technical groups in the Sections and the technical committees of the Institute will be explained further and discussed.

18. *Committee Meetings.* Because of the nature of the Sections committee work, most of the activities of the committee were carried on by means of correspondence. One meeting was held by the committee, January 28, 1947, in New York, during the winter meeting. At this meeting, the entire Sections committee program was reviewed, plans for the delegates' meetings in Montreal were formulated, and plans for the remaining portion of the year were discussed. Minutes of this meeting were sent to all who attended and, in addition, were sent to all Institute board members, District secretaries, and Section chairmen.

COMMITTEE ON STUDENT BRANCHES

Work was continued on arrangements for joint Student Branches, and a proposal was submitted to the directors. After adjustments were made by the committee on constitution and bylaws, the following action was taken by the board. Section 53 was amended to read as follows:

> Sec. 53. The annual Student member dues shall be three dollars, payable in advance, and shall cover the fiscal year of the Institute beginning on May first. The initial dues payment, upon application for enrollment, shall be:
>
> $3.00 if application is filed at Institute headquarters during period February 1 to following July 31;
> $1.50 if application is filed at any other time.
>
> The renewal of Student membership shall uniformly require payment of the dues of $3.00 for the fiscal year beginning May first. The term of Student membership shall extend to the end of the fiscal year, April 30, in which student status ceases, or the Student member has attained the age of 21, whichever is later, except in those cases where the fiscal year ends within six months after graduation. In such cases, Student membership may be continued for one additional fiscal

> year, or to the end of the fiscal year in which the age of 21 is attained. For those students who are not devoting their entire time or a major part of their time to studies, the term of Student membership shall not extend over a period of more than five years.

Section 61 was amended by the addition of the following to the end of the section:

> In the case of a joint Student Branch, as further referred to in Section 64, a counselor shall act jointly with the duly appointed counselors of other national engineering societies in matters affecting the student society and the welfare of its members.

Section 64 was replaced with the following text:

> Sec. 64. An established student engineering society in a college or technical school of recognized standing may, upon application of its officers and a member of the Institute connected with the school, and the approval of the board of directors, become associated with the Institute. A society so associated also may be associated jointly with other national engineering societies approved by the board of directors as having similiar requirements and interests. If so jointly associated, it shall be known as a "Joint Student Branch," otherwise it shall be known as a "Student Branch."

The following societies are approved for the purpose of this co-operation in engineering education: American Society of Civil Engineers, American Society of Mechanical Engineers, American Institute of Mining and Metallurgical Engineers, American Institute of Chemical Engineers, Institute of Radio Engineers, together with such other national engineering societies as may be approved from time to time by the board of directors as having similar requirements and interests.

District student meetings were reactivated at several locations. R. G. Warner is seeking clarification on the availability of funds for student prize papers, and a report from him is expected at the 1947 summer general meeting in Montreal, Quebec, Canada.

With the membership committee a joint subcommittee was formed on transfer from Student to Associate grade. The purpose of this subcommittee is to explore ways of encouraging transfers for as many students as possible.

Because several schools have made application, a standing subcommittee on the establishment of new Student Branches, has been formed.

Work is under way to secure a set of short papers or essays which will stimulate student interest in the AIEE.

Work was continued jointly with the Sections committee to encourage Section–Branch co-operation. Suggestions concerning this were sent to all Branch counselors.

FINANCE COMMITTEE

The budget approved by the board of directors anticipated continued high revenues from a growing membership and active interest in the Institute's affairs. At the same time, appropriations were made to carry forward the Institute's broad progressive program and to meet the rising cost of its activities.

As of April 30, 1947, the end of the fiscal year operations showed a favorable balance of some $23,500. Receipts, largely as a result of new members, were 7 per cent greater than the previous fiscal year. At the same time, expenditures increased 36 per cent. Though the cash balance in general funds of $6,900 was very much lower than the $81,379 at the beginning of the year, this was offset by an increase in reserve capital fund investments of some $96,000. During this same period, $1,877 was added to the Member-for-Life fund.

The $23,500 operating balance for the past fiscal year compares with about $130,000 in the previous year. In spite of a rapidly growing membership, the sharp upward trend in unit costs, along with such factors as the expanded postwar program and the new progressive publication policy have been responsible for this drop. While the budget as approved by the board of directors for the budget year ending September 30, 1947, was in balance, the subsequent rise in costs and falling off in advertising now make it appear likely that the current budget year may end with an operating deficit.

As shown in the attached audit of the Institute's finances, it has been possible as a result of the operating surpluses of the past several years to build up a substantial reserve capital fund which would be very useful as a cushion against lean years that must be expected. Such a cushion could not, however, long support a program of activities in excess of income. If a balanced budget is to be achieved next year, both the revenue and the expenditure items will have to be examined carefully.

TECHNICAL PROGRAM COMMITTEE

Increased Technical Activities. The technical activities of the Institute are at the highest level in history. The winter meeting program was enlarged to provide for the presentation of 162 papers, 98 of which were *TRANSACTIONS* papers. Both these figures are new meeting records. The enlarged program served a record registration of 3,567 as compared with last year's record of 2,624.

An analysis of the papers presented at this and other meetings held during the year ending April 30, 1947, is given in Table II. This table shows a great increase in the yearly number of papers presented. For the same number of meetings, the tabulations show 208 *TRANSACTIONS* papers compared with 153 presented the previous year, and the 367 total of all papers compares with the total of 212 for the previous year. The large number of sessions, conferences, and papers would indicate that, in general, the Institute is on its way to doubling its activity record of the past several decades. Already the resources available for handling the large amount of technical activity under way at the present time are being strained. The increase may be attributed to growth in membership, the aftermath of the war, enlargement of the field of electrical engineering, and to increased technical activity in general due to the additional attention the Institute has paid to developing full coverage of every area of the profession of electrical engineering.

Expanded Technical Coverage. The committee has worked in close co-operation with the technical activities subcommittee of the committee on planning and co-ordination in its effort to organize the technical committees in a manner which would provide the opportunity of presenting and recording new technical developments more efficiently. This work is described in more detail in the report of that committee. The creation of ten new technical committees has increased the number of these committees serving the Institute by about 50 per cent, which in itself will continue to make available to the Institute an increased number of technical meetings and papers. The committee now is reviewing papers for the newly established Midwest general meeting scheduled to be held in Chicago, Ill., November 3–7, 1947, the meeting having been designed to fit in with the National Electronics Conference to be held earlier in the same week. This kind of co-ordinated activity with other technical organizations also has added to the general activity in the electrical engineering field; each technical committee is attempting to work jointly insofar as possible with other technical bodies which affect it. Each technical committee also has analyzed its own administrative structure and in its meetings under the new group organization setup has traded responsibilities back and forth to the end that definite responsibilities have been allocated clearly and efficiently. This interchange of ideas and responsibilities in itself has resulted in a more complete coverage of the field.

Analysis of Subject Matter. Sessions and conferences on the program of the summer meeting in Detroit reflect subject matter not found on Institute programs heretofore. Full sessions on servomechanisms, industrial control devices, electronic tubes and basic circuits, electronic power conversions, and a conference on electronic instruments were held for the first time. Two sessions were held on industrial power applications, in which members of the Industrial Electrical Engineering Society were invited to participate. Five of the 26 sessions and conferences were concerned with the industrial field.

Analysis of Subject Matter. On the program of the winter meeting, sessions reflecting work in the newer fields were held as follows: servomechanisms, electronic instruments, metallic rectifiers, applications in the textile industry, and three sessions in the field of land transportation—light traction, electric railways, and Diesel-electric locomotives. Among the recently developed subjects discussed in conferences were energy sources, electronic devices and methods, large scale computing devices, and aircraft safety.

At this meeting also, there was an increase in activity in the industrial field, as 7 out of 40 sessions and conferences were devoted to it. A number of the new sessions and conferences were in the field of electronics, not to mention other numerous

Table II. Numbers of Papers Presented During the Year Ending April 30, 1947

Meeting	District	Advance Copy Only	Conference	Transactions	Total
Southern District, Asheville	9	3		2	14
Summer, Detroit		3	25	73	101
Pacific Coast, Seattle		4	2	22	28
Great Lakes District, Indianapolis	15	1	10	3	29
Winter, New York		5	59	98	162
North Eastern District, Worcester	23			10	33
Total	47	16	96	208	367

electronic applications that may be found throughout the various sessions on these programs.

Demonstrations. Increase in the number of demonstrations in conjunction with the presentation of papers was noteworthy at the winter meeting. Demonstrations took place in the sessions on electronic instruments, television, the symposium on limitations of light production, the symposium on rural telephone facilities, and the conference on some new electronic devices and methods. These demonstrations added to the effectiveness of the presentations and the interest in the sessions.

Plans for the Ensuing Year. With the increase in the number of Institute meetings, both general and District, and with the added number of technical committees and greater coverage of the field accomplished by the recent reorganization work, the committee's forecast of last year on future activities already begins to look entirely too conservative. It now looks as if the average number of papers, instead of being either the 150 to 200 experienced in the past or the 270 forecast last year, will be well over the 300 mark, with the consequent necessity of increasing the annual number of sessions and conferences.

PUBLICATION COMMITTEE

One of the fundamental purposes of the Institute is the dissemination to its members of information concerning new theories, new apparatus, and new developments throughout the electrical field. To accomplish this objective, the bylaws assign to the publication committee full responsibility for "supervision of the monthly journal, *ELECTRICAL ENGINEERING*, *TRANSACTIONS*, and the other publications of the Institute, including the form, size, and arrangement of these publications; also decisions regarding the publication of papers, discussions, and all other matter available for publication; and the formulation and carrying out of plans for bringing into practice the policies regarding Institute publications that may be determined from time to time by the board of directors." Incidental to its responsibility under this objective, and pursuant to actions of the board of directors at its May 1946 and subsequent meetings, the AIEE publication committee during 1946 gave especial attention to the development of ways and means of improving the Institute's publications policy and procedure with the objectives of better serving the greatly enlarged and rapidly growing membership and of covering adequately the active and ever-growing membership and of covering adequately the active and ever-growing electrical field.

Resulting modifications in AIEE policy and procedure were ratified by the board of directors at its August meeting and implemented by necessary budget appropriations at its October meeting for the year 1946–47. Although this was very late in the publication year, and material for the January 1947 issue of *ELECTRICAL ENGINEERING* already was at least partially committed and in work, special efforts on the part of the publication staff enabled initiation of the major approved changes beginning with the January 1947 issue of *ELECTRICAL ENGINEERING*. As a matter of record and reference, the essential features of AIEE publication policy and procedure under these approved modifications are set forth in the following paragraphs.

Under the revised publication plan, the *TRANSACTIONS* section has been eliminated from *ELECTRICAL ENGINEERING*, its place being taken by a new series of pamphlet publications under the reconstituted name, AIEE *PROCEEDINGS*, each of which will carry one technical, paper and related discussions, literally an advance preprint of the ultimate *TRANSACTIONS*. Individual members are given the opportunity, through coupons published periodically in *ELECTRICAL ENGINEERING*, to select designated groups of these technical papers to be received free of charge, and other papers to be received as desired at a nominal charge to cover actual cost. More specifically, the current publications and policy of the Institute are described in the following paragraphs.

1. ELECTRICAL ENGINEERING. Coincidental with the elimination of the *TRANSACTIONS* section, the general interest content of *ELECTRICAL ENGINEERING* has been expanded, enhanced, and given greater flexibility to satisfy more fully the current and future requirements of the membership. Subject only to general policy, the management and publication of *ELECTRICAL ENGINEERING* will be entirely the responsibility of the editor.

The contents of the monthly will be divided broadly into two general categories:

1. General articles, to be drawn from all currently available sources, selected on the basis of timeliness and general-interest value to the membership at large.

2. News material, appropriately reflecting all AIEE and related activities, also reflecting other current activities of interest and significance to the membership.

Summary abstracts of technical papers will continue to be published as far as possible in advance of the meetings at which the papers are scheduled for presentation.

A more aggressive advertising policy is being instituted, to capitalize more fully upon the established prestige and substantial standing of *ELECTRICAL ENGINEERING*. Some improvement has been effected in the weight and quality of paper, and further improvements are contemplated as conditions permit.

Distribution of *ELECTRICAL ENGINEERING* will continue to be made automatically to the entire AIEE membership, including Students; to be available also to nonmembers at an appropriate subscription price in accordance with postal regulations and as provided in AIEE bylaws.

2. PROCEEDINGS. For the purpose of better and more promptly serving those among the membership who are interested especially in the full and complete technical and mathematical details of subject matter within the fields of their particular professional interest, a new series of pamphlet publications has been established, reactivating the name, AIEE *PROCEEDINGS*. These *PROCEEDINGS* contain the full text of all papers approved by the technical program committee for publication in *TRANSACTIONS* and for presentation at general or District meetings, together with all discussions of those papers as approved by the technical program committee; also may contain "miscellaneous (ACO) papers" approved by the technical program committee, and other appropriate material. Thus, the *PROCEEDINGS* is planned to contain all material previously published in the *TRANSACTIONS* sections of the 12 monthly issues of *ELECTRICAL ENGINEERING*, all the material previously published in the two semiannual "Supplements to *ELECTRICAL ENGINEERING—TRANSACTIONS* Section," and in addition other meetings material previously unpublished.

Distribution of *PROCEEDINGS* is being made on a selective basis through the use of coupons published from time to time in *ELECTRICAL ENGINEERING*, each Fellow, Member, and Associate of the AIEE being given an opportunity to select for receipt free of charge a limited quantity designed to be sufficiently generous to enable the average member to obtain those papers in which he is concerned most intimately; additional copies are available at cost. The first distribution of *PROCEEDINGS* began in April 1947, carrying winter meeting papers.

3. Annual TRANSACTIONS. Current policies and procedures with reference to AIEE *TRANSACTIONS* are being continued without change, except that the flexibility introduced by the previously discussed changes in publication procedure now enable discussions to be assembled with the papers to which they apply. Distribution continues on the basis of advance order; to the AIEE membership at cost, to others at appropriately higher prices. Sharply increased production costs will require an upward adjustment of price for the 1948 volume.

4. *Preprints.* To encourage and facilitate discussion of technical papers at general and District meetings, the practice of issuing advance pamphlet copies or preprints of technical program papers by the photolithographic or other appropriate process is being continued. Distribution is made through two principal channels:

1. Through the interested technical committee a limited quantity without charge for official use.

2. Through general sale, to the entire AIEE membership at cost and to others at 100 per cent above members' price.

Heavy increases in production costs during the past year have necessitated an adjustment in the price schedule for this material, which now stands as follows:

Table III. Advance Pamphlet Prices

Size		At Headquarters or Meeting, Cents	By Mail, Cents
12 pages or less:			
	To members	15	20
	To nonmembers	30	35
16 pages:	To members	20	25
	To nonmembers	40	45
20 pages:	To members	25	30
	To nonmembers	50	55
24 pages:	To members	30	35
	To nonmembers	60	65
28 or more:			
	To members	35	40
	To nonmembers	70	75

5. *Special Publications.* To provide a facility in a field of publication services heretofore not satisfied adequately by the Institute, a series of "AIEE Special Publications" has been established, and its use is encouraged. It is contemplated that such publications will be issued from time to time, and in appropriate relation to other AIEE publications, to accommodate material of especial value and importance in its field, but of limited general interest or applicability, or material peculiarly convenient and appropriate in the form of separate or substantially bound books or booklet.

Special publications are to de issued on an entirely self-supporting basis, the proceeds from the sales in effect constituting a revolving fund for continuation and stimulation of the project. Distribution will be on the basis of individual order; at cost to the AIEE membership, to others at 100 per cent above members' prices.

6. *Reprint Service.* As a special service which has proved to meet many membership needs, the practice of publishing quantities of reprints or preprints of AIEE material is being continued. Such reprints usually are produced on the basis of specific order or anticipated need; in any event, on an entirely self-supporting basis.

7. *Annual Index.* A complete composite "AIEE Annual Index" is planned, to cover appropriately the content of *ELECTRICAL ENGINEERING, PROCEEDINGS, TRANSACTIONS,* and special publications, continuing the basic alphabetical multientry subject-listing system originally developed by *ELECTRICAL ENGINEERING* and used with eminent success over a period of many years. Distribution is automatic and without charge to AIEE membership and to regular subscribers to AIEE publications; upon request to others.

8. *Yearbook.* Publication is continuing without change. Distribution automatic to Section, District, and national officers and national committee personnel; to others upon request.

9. *Conference Papers.* The informal AIEE conference papers will be treated very much as in the past. As such, they do not have automatic publications status, although the editor of *ELECTRICAL ENGINEERING* specifically is authorized to make appropriate use of conference material subject to the approval of the authors involved.

An accompanying tabulation shows the number of pages of various classes of material published during the last three years as compared with 1941 which was the last prewar year. The cancellation of meetings in 1945 caused a sharp drop in the amount of material available for publication, the effects of which were carried over somewhat into early 1946.

Considerable difficulty has been experienced throughout the year in obtaining a satisfactory supply of paper, because of industry conditions, although rationing as such no longer exists.

Several changes were made in the AIEE publications staff with the objective of improving the average level of technical qualifications. Overcrowded conditions in the Engineering Societies' Building necessitated relief in some direction, and hence the publications department as an operating unit of the headquarters organization was elected for removal to commercial office building space. This includes both editorial and advertising offices.

Much remains to be done in developing the full potentiality of the new publication policy, and full effort toward that objective is being continued by the publications staff and the publications committee.

COMMITTEE ON INSTITUTE PUBLICITY

The committee on institute publicity undertook as its first job to plan the publicity campaign for the 1947 winter meeting. The experience of earlier committees in handling this problem was available and was drawn upon freely. It was apparent from these earlier experiences that there had not always been sufficient time to do a thoroughly integrated job. Accordingly the Raymond C. Mayer public relations organization was engaged as of December 1, 1946, to help plan a publicity campaign and to prepare material for distribution through various publicity mediums. The technical program committee and the winter meeting committee co-operated wholeheartedly in developing the program for the meetings which would take full advantage of publicity possibilities.

Mr. Mayer assisted in this general planning of the program, and his organization prepared publicity releases on many of the papers that were presented. Each of these was reviewed by the chairman of the committee, or his representative, and all were distributed to mediums considered appropriate for the subject in hand. In addition the Mayer organization issued general releases regarding the meeting activities and some of its personnel, as well as releases concerning the medal presentations. Photographers were made available for press pictures of the medalists and other groups, as desired by press representatives.

The Mayer organization also arranged for clippings, through organized clipping services, and these are available to the committee. There was very wide use of released material in many mediums, according to a survey by Mr. Mayer, several times the coverage previously attained.

No special plan has been set up to conduct a similar campaign under the committee's auspices for the summer general meeting, although it is planned to investigate the matter of general publicity for that meeting through the local Montreal organization.

The committee has given some thought to the possibility of aiding Student Branches in publicizing Institute activities. It seems clear that students who will become engineers, eligible for membership in the Institute, should have their interest in the Institute aroused, as a means of stimulating membership. Thus far very little has come of this effort, but several of the counselors have volunteered suggestions. This matter should be studied further.

In addition to the effective use of a sound publicity program as a means of stimulating Institute growth, such a program is valuable as a means of enhancing the prestige of present members and of the engineering profession as a whole. It also serves to fulfill an obligation to the public which contributors to scientific knowledge should recognize. Obviously this involves more than the issue of news releases. The

Table IV. Numbers of Pages of Published Material

	ELECTRICAL ENGINEERING			TRANSACTIONS Only		
Year	General Interest Articles	News	Transactions Section	Technical Papers	Discussions	Total
1941	337	281	600	542	268	2,028
1944	246	214	738	493	231	1,922
1945	255	225	736	121	143	1,480
1946	285	315	832	254	120	1,806

Table V. Membership Statistics for Fiscal Year Ending April 30, 1947

	Honorary Members	Fellows	Members	6 Year Associate	Associate	Subtotals	Totals
Membership April 30, 1946	9	988	6,892	7,348	9,853		25,090
Additions							
New members qualified		2	292		2,084	2,378	
Former members reinstated or re-elected			114	47	116	277	
Subtotals	—	2	406	47	2,200	2,655	
Transfers		77	439	1,007		1,523	
Totals	—	79	845	1,054	2,200	4,178	
Deductions							
Died		22	58	35	30	145	
Resigned		2	54	145	111	312	
Dropped		4	48	214	544	810	
Subtotals	—	28	160	394	685	1,267	
Transfers			77	356	1,090	1,523	
Totals	—	28	237	750	1,775	2,790	
Net changes		51	608	304	425	1,388	
Membership April 30, 1947	9	1,039	7,500	7,652	10,278		26,478

Table VIII. Record of AIEE Membership

Year	Total May 1	Year	Total May 1	Year	Total May 1
1884	71	1906	3,870	1927	18,344
1885	209	1907	4,521	1928	18,265
1886	250	1908	5,674	1929	18,133
1887	314	1909	6,400	1930	18,003
1889	333	1910	6,681	1931	18,334
1890	427	1911	7,117	1932	17,550
1891	541	1912	7,459	1933	17,019
1892	615	1913	7,654	1934	15,230
1893	673	1914	7,876	1935	14,269
1894	800	1915	8,054	1936	14,600
1895	944	1916	8,202	1937	15,308
1896	1,035	1917	8,710	1938	16,078
1897	1,073	1918	9,282	1939	16,605
1898	1,098	1919	10,352	1940	17,213
1899	1,133	1920	11,345	1941	17,886
1900	1,183	1921	13,215	1942	18,944
1901	1,260	1922	14,263	1943	20,161
1902	1,549	1923	15,298	1944	21,407
1903	2,229	1924	16,455	1945	23,072
1904	3,027	1925	17,319	1946	25,090
1905	3,460	1926	18,158	1947	26,478

committee has given some thought to this broad question but has no report to make at this time.

MEMBERSHIP COMMITTEE

During the past year, membership has continued to climb. On April 30, 1947, the total membership was 26,478. This is an all-time record, and almost 1,500 members more than the preceding year. While the rate of increase in membership was not quite so high as the previous year, this was caused by the fact that 475 members were dropped who previously had maintained inactive status because of military service.

Indications are that the membership will continue to increase steadily during the next several years. Table VII shows the tremendous increase in number of Student members, that is, 9,021 at the end of April 1947, compared with 5,087 at the end of April 1946. This increased reservoir of Student members should stimulate membership during the next few years.

There is a slight increase in members who are in arrears with their dues. At the end of April 1947, there were 1,090 members in arrears, whereas a year ago there were only 954 members. It is hoped that increased activity of the Section membership committees will improve this situation.

During the past year, the number of members carried on inactive status was reduced from 1,809, as of April 30 last year to 361 as of April 30 this year. Of the 361 on the inactive list, about 70 are members who are still in the service and who have requested continuance of inactive status. About 290 are members located abroad who will be permitted to become reinstated upon notification. Incidentally, this opportunity to become reinstated is also available to the 475 members who were in the service and have been dropped as of April 30, 1947.

Activity of the Section membership committees is reflected by the fact that 3,269 applications for membership were received during the year.

Table VI. Number of Applications Received From Student Members and From All Others

Year Ending April 30	Students	All Others	Total
1947	938	2,331	3,269
1946	308	2,453	2,761
1945	249	2,179	2,428
1944	466	1,908	2,374
1943	783	1,431	2,214

Table VII Number of Student Members as of April 30

Year	New Applications	Renewals	Total
1947	5,092	3,929	9,021
1946	2,574	2,513	5,087
1945	2,326	2,287	4,613
1944	2,242	2,656	4,898
1943	2,512	3,200	5,712

An effort was made during the past year to decentralize the activities of the membership committee as much as possible. It is believed that more effective membership work is done at the Section level, and everything possible should be done to support the Section membership committee chairmen. The responsibility was assigned to each District vice-chairman of the membership committee to assist the Section chairmen in his District. Progress has been made along this line.

A talk on benefits of membership in AIEE was prepared for presentation before the Student Branches. In the preparation of this talk, the membership committee co-operated closely with the committee on Student Branches. It is planned to have this talk presented before all Student Branches this fall to stimulate Student membership.

The membership committee thinks it desirable to stimulate transfers from Student membership to Associate membership immediately upon graduation from college. A joint subcommittee with members from the membership committee and Student Branches committee is working on this subject and expects to present a report of a plan by this fall.

A subcommittee of the membership committee is revising the Section membership committee manual. This revised manual should be ready by the latter part of this year. Revision of the booklet, "Accomplishments of the AIEE in the Engineering World," is now under way. Both of these publications are valuable tools for Section membership committees.

The preceding membership statistics are supported by Tables V, VI, VII, and VIII.

BOARD OF EXAMINERS

Statistics relating to the number of cases handled by the board of examiners during the year 1946–47 are given in Table X. The past year shows an increase of 71 per cent over 1945–46, indicative of the increasingly widespread interest in AIEE activities. The expeditious handling of this rapidly growing number of cases on a monthly meeting schedule has been possible only through the 1945 increase in membership of the examiners to 19.

The board of examiners wishes to reiterate its pleas of previous years for careful preparation of applications for both admission and transfer to Member and Fellow. Though the situation has improved through the co-operation of national and Section committees, it is still necessary for both the examiners and headquarters to spend considerable time obtaining more detailed information on professional records and added references to bring a sizeable number of cases into conformity with the constitutional requirements.

In Table XI figures on cases handled by the board over a 5-year period are given. Of particular interest are the percentage rejections for admission and transfer to Member, which with one exception are al-

Table IX. Deaths of AIEE Members Reported in "Electrical Engineering"

Name	Date of Election	Date of Death	Grade at Death	Obituary Notice in "Electrical Engineering"
Adams, Edward L.	A '24	May 4, '46	A	July '46, p. 357
Arter, Roy C.	A '39	Sept. 22, '46	A	Dec. '46, p. 588
Blair, Samuel Robert	A '29	Apr. 17, '46	A	July '46, p. 358
Blume, Louis F.	A '09	Aug. 14, '46	F	Nov. '46, p. 539
Browning, Jr., Elmer E.	M '38	Jan. 8, '47	M	Mar. '47, p. 306
Burton, William Corwin	A '93	Apr. 18, '46	M	Aug.–Sept. '46, p. 421
Butz, Jr., Arthur N.	A '45	Dec. 7, '46	A	Feb. '47, p. 194
Chambers, W. L.	A '45	May 18, '46	A	July '46, p. 358
Cooke, Jr., Thomas L.	A '41	May 27, '46	A	Aug.–Sept. '46, p. 422
Crane, Albert S.	A '04	Aug. 26, '46	M	Oct. '46, p. 476
Creasey, John W.	A '20		M	Dec. '46, p. 587
Curry, Aubrey R.	M '34	Feb. 6, '46	M	July '46, p. 358
Czarnecki, Frank C.	A '15	Dec. 25, '46	A	Mar. '47, p. 306
Daniels, Harold P.	A '02	July 1, '46	A	Oct. '46, p. 476
Dearborn, Richard Harold	A '07	Mar. 21, '46	F	July '46, p. 357
Dively, William L.	A '27		A	Nov. '46, p. 539
Dixon, Walter C.	M '36	Feb. 28, '46	M	June '46, p. 289
Elliott, Edward Byron	A '17	Mar. 14, '46	M	July '46, p. 357
Filer, William F.	M '26	June 24, '46	M	Nov. '46, p. 539
Fisken, John Barclay	A '03		F	Aug.–Sept. '46, p. 421
Francisco, Ferris L.	A '04	Oct. 11, '46	M	Dec. '46, p. 587
Garfield, Alexander S.	A '98	Dec. 5, '44	F	Jan. '47, p. 97
Goldstone, Philip	M '24	Apr. 29, '46	M	Aug.–Sept. '46, p. 422
Griffes, Eugene V.	A '96	July 21, '45	A	Jan. '47, p. 98
Griffith, Hoyt D.	A '45	Jan. 4, '47	A	Mar. '47, p. 306
Hardy, Shaw H.	A '46	May 26, '46	A	Aug.–Sept. '46, p. 422
Harkins, John	A '21	May 21, '46	M	July '46, p. 358
Harrison, James	A '03	June 16, '46	F	Dec. '46, p. 587
Herrington, C. R.	A '45	Sept. 5, '46	A	Dec. '46, p. 587
Hobart, Henry M.	A '94	Oct. 11, '46	F	Dec. '46, p. 586
Hood, Samuel Bingham	M '14	Mar. 9, '46	M	May '46, p. 232
Houser, Kenneth O.	A '44	Apr. 16, '46	A	Aug.–Sept. '46, p. 422
Jackson, Jack E.	A '38	Nov. 1, '46	A	Feb. '47, p. 194
Jain, Ranjit Singh	M '39	Apr. '46	M	Dec. '46, p. 588
Kane, John J.	M '15	Nov. 8, '46	M	Jan. '47, p. 98
Kerr, Milton P.	M '41	Oct. 7, '46	M	Dec. '46, p. 588
Killingsworth, Henry M.	A '45	June 4, '46	A	Aug.–Sept. '46, p. 422
Kopp, Otto A.	A '09	Dec. 19, '46	M	Apr. '47, p. 408
Little, John J.	A '02	Dec. 26, '46	M	Apr. '47, p. 408
Macdonald, James E.	A '03	Aug. 8, '46	M	Nov. '46, p. 538
Margolin, Samuel Charles	A '32	Jan. 3, '46	A	June '46, p. 289
Matthies, William H.	M '26	Oct. 20, '46	F	Dec. '46, p. 587
Mini, Jr., Joseph	A '08	Aug. 24, '46	A	Jan. '47, p. 98
McAllister, Addams S.	A '02	Nov. 26, '46	F	Feb. '47, p. 193
Pattison, Frank A.	A '91	Sept. 18, '46	F	Nov. '46, p. 538
Rodman, Walter S.	A '07	Dec. 31, '46	F	Mar. '47, p. 305
Roy, Kiron Chandra	A '31	Oct. 19, '45	A	May '46, p. 232
Sachs, Joseph	A '92	Nov. 15, '46	F	Feb. '47, p. 194
Scanlon, J. Leo	A '28	Jan. 20, '47	M	Apr. '47, p. 408
Schneider, Frederick W.	A '17	Dec. 28, '46	A	Mar. '47, p. 306
Scott, Edgar George	A '10	Dec. 25, '45	M	July '46, p. 357
Shapiro, Louis	A '36	Apr. 28, '46	A	July '46, p. 357
Shearer, Harry Foster	M '45	May 24, '46	M	Aug.–Sept. '46, p. 421
Shepard, Robert B.	A '25	June 20, '46	F	Aug.–Sept. '46, p. 421
Smith, Frank W.	A '05	July 22, '46	M	Oct. '46, p. 476
Smith, William L.	M '22	Feb. 21, '47	F	Apr. '47, p. 408
Southgate, George T.	A '11	Nov. 8, '46	M	Mar. '47, p. 305
Sprong, Severn D.	A '03	June 27, '46	F	Aug.–Sept. '46, p. 421
St. Clair, Byron W.	A '17	Apr. 4, '46	M	June '46, p. 289
Stephens, Charles E.	M '22	Nov. 19, '46	M	Feb. '47, p. 194
Stephens, Howard O.	A '18	May 15, '46	M	Feb. '47, p. 194
Stevenson, Francis Leslie	A '03	Feb. 13, '46	M	July '46, p. 357
Stevenson, Jr., Alexander R.	A '20	Aug. 28, '46	F	Oct. '46, p. 476
Stiefel, Karl J. J.	A '39	Oct. 28, '46	A	Mar. '47, p. 306
Stockwell, Frank C.	A '12	Dec. 29, '46	M	Mar. '47, p. 305
Swoboda, Adolph R.	A '06	Oct. 20, '46	M	Jan. '47, p. 98
Tabossi, Hector	A '12	June 15, '46	M	Dec. '46, p. 587
Thompson, Harry Lee	A '21	Mar. 24, '46	A	June '46, p. 289
Trench, Robert Butterfield	A '41	Apr. 21, '46	A	July '46, p. 358
Van Bokkelen, W. R.	A '12	May 22, '46	M	Aug.–Sept. '46, p. 421
Waring, James M. S.	A '06	Oct. 23, '46	A	Dec. '46, p. 587
Watson, Leon A.	M '35	Apr. 18, '46	M	July '46, p. 358
Way, Sylvester B.	A '03	Sept. 20, '46	F	Dec. '46, p. 586
Weiss, Otto	M '46	Mar. 28, '46	M	Aug.–Sept. '46, p. 422
Wilcox, Stanley C.	A '38	June 22, '46	M	Oct. '46, p. 476
Wolff, Frank Alfred	A '99	Mar. 28, '46	M	June '46, p. 289
Young, Herbert W.	A '05	Nov. 25, '46	F	Feb. '47, p. 194
Zimmerman, Mathias, W. F.	M '43	Mar. 23, '46	M	June '46, p. 290

Table X. Applications for Admission and Transfer 1946–1947

Applications for Admission		
Recommended for grade of Associate	2,052	
Re-elected to the grade of Associate	114	
Not recommended	3	
		2,169
Recommended for grade of Member	390	
Re-elected to the grade of Member	20	
Not recommended	75	
		485
Recommended for grade of Fellow	2	
		2
Applications for Transfer		
Recommended for grade of Member	424	
Not recommended	34	
		458
Recommended for grade of Fellow (by proposal)	64	
Recommended for grade of Fellow (by invitation)	14	
Not recommended	3	
		81
Students		
Recommended for enrollment as Students		3,931
Total		7,126

most constant. No figures are given on unfavorable actions concerning Fellow grade, as such rejections are at a negligible minimum. Similar studies made earlier over a much longer period have resulted in almost identical figures.

Table XI. Five-Year Summary 1942–1947

			Admission to Member		Transfer to Member			
Year	Students	Associates	Total	Per Cent Rejected	Total	Per Cent Rejected	Transfer to Fellow	Total Cases
1946–1947	3,931	2,169	485	15+	458	7+	83	7,126
1945–1946	1,568	1,601	422	5+	478	5+	96	4,165
1944–1945	1,927	1,824	445	15+	434	3+	63	4,693
1943–1944	2,109	1,591	309	15+	381	4+	75	4,465
1942–1943	2,317	1,982	262	14+	285	4+	49	4,895

COMMITTEE ON TRANSFERS

Realizing that many Sections have not, in recent years, been taking the interest they should in encouraging their eligible members to apply for higher grades of membership, and, believing that the lack of a uniform guide was the primary reason for the apparent disinterest, the committee on transfers concentrated its efforts on the preparation of a general guide supplemented by thoroughly developed suggestions to the Sections.

The general guide, itself, was prepared and submitted by the board of examiners. This guide under the title, "Transfer Procedure," was studied carefully and endorsed, without revision, by the committee on transfers. However, a wide variety of suggestions were received both from the members of the committee and from several Sections which obviously had maintained interest in grade transfer work. The suggestions were enlightening and helpful.

The Sections committee became interested in the study being made by the committee on transfers, and, finally, a joint report was made by these two committees. This joint report was duplicated in New York and mailed to all Section chairmen and secretaries, and to all members of the board of examiners, Sections committee, committee on transfers, and other interested members.

The high points of the report, dated December 30, 1946, in supplement to the "Transfer Procedure" were that:

1. Each Section should have a grade transfer committee as a standing committee.

2. Each local committee should be a continuing committee operating throughout the calendar year.

3. Each local committee should be sufficiently large to represent fully the professional groups and industries within the area.

4. Each local committee should be composed of the best known, most highly respected, and most representative men in the Section.

5. Any candidate for transfer should be considered by a group of the local committee having grades no lower than the grade being considered for the candidate.

COMMITTEE ON CODE OF PRINCIPLES OF PROFESSIONAL CONDUCT

As no important matters came before this committee during the year, it held no formal meetings, but carried on all of its activities by correspondence.

Various members of the committee have been active in their own geographical areas in bringing the attention of engineers and others to the Institute's "Code of Principles of Professional Conduct" and in furthering the Engineers' Council for Professional Development's "Canons of Ethics for Engineers."

Several members also have taken an active part in urging upon their representatives in the Congress of the United States the importance of passing Senate Bill 360, in an endeavor to relieve engineers and other professional men from the conditions which force engineers into collective bargaining dominated by workingmen's unions.

At the time of the last report, an alleged violation of professional ethics by an Associate was being investigated. This investigation finally was dropped when the complainants would not furnish detailed evidence, and the alleged violator would not answer any requests of the committee for a statement of his side of the case. A report of this matter was submitted to the AIEE.

COMMITTEE ON REGISTRATION OF ENGINEERS

The committee on registration of engineers has devoted most of its attention to the problem of co-operating with other organizations on registration of engineers, and in keeping the Model Law in accordance with present thinking. The committee recommended the following resolution, which was approved by the board of directors:

RESOLVED: That the legal recognition of engineer-in-training status for recent engineering college graduates and other equally qualified persons is beneficial to the public and to the profession. This practice distinguishes men intending to become professional engineers from others not so qualified or so intending. It further is resolved that this resolution be published in *ELECTRICAL ENGINEERING* and that members be encouraged to assist groups striving to adopt this practice in the states where they reside.

The committee also has given consideration to the selection of personnel to serve on state registration boards and the methods by which this selection is made in various states. The committee feels that the Model Law could be improved in several aspects and particularly regarding the provisions for the engineer-in-training.

COMMITTEE ON CONSTITUTION AND BYLAWS

On December 3, 1946, the committee made the following recommendations to the board of directors, which were adopted by the board, January 29, 1947.

1. Amendments changing the word "convention" to "meeting" wherever it occurs in the bylaws, and changing Section 27 so that the four general meetings will be known in future as the "winter general meeting," the "summer general meeting," the "Midwest general meeting," and the "Pacific general meeting." Submission of a constitutional amendment at the next convenient opportunity, to substitute the words "general meeting" for "convention."

2. Amendment to transfer Hawaii to District 8 with corresponding change of the map of Districts of the Institute.

3. Amendment of Section 48 to make changes in the allotment of funds to Sections.

On December 27, 1946, the committee made the following recommendations to the board, and these were adopted also on January 29, 1947.

1. Amendments of Sections 53, 61, and 64 of the bylaws to permit the formation of joint Student Branches with other national engineering societies, and to extend the term of Student membership until a Student member has reached the age of 21, if he should be graduated before reaching his majority. Submission of a constitutional amendment, Article IV, Section 16, at the next convenient opportunity, to enable joint Student members to become Associate members in accordance with Section 57 of the bylaws.

2. Amendment of Section 33 to clarify it, and in Districts having less than five Sections to enable the District executive committee to act as the co-ordinating committee for the District.

On April 16, 1947, the committee made the following recommendations to the board, and these will be presented at the June meeting of the board.

1. Amendment to the bylaws consisting of the deletion of Section 8, pertaining to the preliminary consideration of applicants for transfer from Associate to a higher grade of membership.

2. Amendment of Section 41 to delete reference to the finance committee, as this section relates to Section territory and does not involve financial matters.

COMMITTEE ON PLANNING AND CO-ORDINATION

The committee has carried forward actively the project assigned to it by the board of directors nearly two years ago and subsequently interpreted and re-emphasized by board resolution or adoption of the committee's several recommendations. The committee held four meetings and carried on a considerable correspondence, but the real work was done by its two subcommittees.

The subcommittee on technical activities held monthly meetings and supplemented frequent joint sessions with the technical program committee by a truly voluminous correspondence with members of the technical committees.

During the past year the subcommittee has devoted its effort almost entirely to a study of a reorganization of the Institute's technical activities and the preparation of recommendations to the board on how this reorganization might be accomplished under the directive set forth in a resolution adopted by the board at its meeting in Asheville, N. C. in May 1946. That resolution specified:

(1) that such additional technical committees should be organized as may be needed to cover the important items of electrical technology; (2) that these technical committees should be grouped in appropriate divisions or groups with a steering committee for each group fairly compact in numbers and reasonably concentrated geographically to promote effective action; (3) that the members of the steering committees be appointed by the president, and the members of the technical committees be appointed by their respective steering committees, all to serve for one year; (4) that each year the group steering committees, in addition to appointing their several technical committees, make recommendations to the president through the secretary on the membership and organization of their respective successor committees, including at least two alternates for each chairmanship; (5) that in such recommendations the steering committees provide for a turnover of at least 25 per cent of the steering committee personnel each year. Further, that it is the intent of this board that the responsible committees should proceed with such changes as they may determine to be necessary and proper to effectuate these principles, unless the proposed changes are at variance with either the constitution or the bylaws, in which event they shall be referred back to this board for further consideration.

Pursuant to this directive, the subcommittee has recommended, and the board has approved, the formation of four co-ordinating committees and the establishment of 20 new technical committees. Some of these technical committees are new, and some supplant others recommended for retirement. Including the committee on education, the status of which was changed from that of a technical committee to that of a general committee, there were ten technical committees that were recommended to be withdrawn, thus making a net increase of ten in the number of technical committees recommended to be in operation. A résumé of the proposed setup follows:

Power Group

Power substations
Power rotating machinery
Power transformers and regulators
Power generation
Power system operation
Power transmission and distribution systems
Insulated power cables
Power protective devices
Power switchgear
Power relays
Power systems application of carrier current
Power converters—electronic

Industry Group

Electric welding
Electric heating
Industrial power systems
Mining, metal forming, and rolling
Industrial control devices and equipments
Chemical, electrochemical and electrothermal
Machine tools, material processing, and fabrication

General Applications Group

Air transportation
Domestic and commercial application
Land transportation
Production and application of light
Marine transportation

Communication and Science Group

Communication
Basic sciences
Electronics
Instruments and measurements
Nucleonics
Therapeutics

Except for the nucleonics committee, the new committees were formed from strong existing subcommittees.

Also the chairmen of two of the general committees, education and research, were made ex-officio members of the technical program committee, in addition to the other committee chairmen already having that status.

It is recognized that the proposed reorganization does not achieve perfection. However, the responses received from interested members indicate a remarkable degree of concurrence that the changes are a step in the right direction and a satisfactory basis for trial. Experience with the new setup will show what further changes are necessary or desirable.

The principal activity of the subcommittee on professional activities continued to be its study of organization of the engineering profession. Through meetings throughout the country and the use of a questionnaire, it obtained opinions and expressions from nearly 1,500 Institute members in the several fields of technical interests and in various age and employment groups. The subcommittee made a formal report which included results of the survey and recommendations for consideration of a plan of organization based on that originally proposed as plan *D*, but modified to incorporate certain features from plans *B* and *C*. In effect, this plan proposes an over-all engineering organization composed of individual members, which would further the nontechnical needs and aspirations of engineers in all fields. Under the proposed plan, the present technical societies would continue to function practically without change in their respective technical fields. Included was a skeletonized constitution and certain other fundamental principles regarding classification of members, dues, publication, and so forth.

The committee accepted the report and submitted it to the board of directors. The board authorized immediate publication of the survey portion of the report. (This appeared in the April 1947 issue of *ELECTRICAL ENGINEERING*.) The board also approved early publication of the entire report, except for the plan of procedure. (This appeared in the May issue of *ELECTRICAL ENGINEERING*.) The report was referred to a special committee consisting of the president and four past presidents for editing and the preparation of recommendations to the board as to its disposition.

As a prerequisite to any plan of organization for the engineering profession, it was believed that there is a need for uniform grades of membership in all the societies. A study therefore was made of the present membership requirements of the Founder Societies, and recommendations prepared for grades of fellow, member, associate, and student. The board approved the principle of uniform grades, agreed to urge various other societies to study the matter and consider adoption of uniform grades, and indicated its willingness to recommend these requirements for adoption by the membership of the Institute, if agreement can be reached with the other societies on uniform grades of membership.

An investigation to determine whether the creation of a new Institute office might be justified led to the decision to recommend that greater use be made of the District organizations and the vice-presidents to relieve the president of some of the burdensome duties of his office. The recommendations made were submitted to and approved by the board. Consequently, it is now the practice to have the secretary of the Institute call a special meeting of the incoming, outgoing, and holdover vice-presidents during the summer meeting, at which they are informed of their duties in co-ordinating the work in the Districts. The Sections are advised on the method of obtaining official speakers and that all requests for official visits are cleared through the respective vice-president. It further was agreed that presidential Section visits do not take precedence over other Institute obligations.

The subcommittee considered a suggestion that provision be made for discussions and interchange of information, within the Institute, on management problems. As it is apparent that the need exists, the establishment of a committee on management was recommended and approved by the board.

A suggestion had been received that, with the increasing number and activity of Institute committees, consideration be given to organizing the nontechnical committees in groups similar to the plan proposed for the technical committees in accordance with the Asheville resolution. The subcommittee recommended that certain of the nontechnical committees be grouped as administrative, professional, and general, and that the first two groups named establish co-ordinating committees consisting of the respective committee chairmen. The general committees, such as Sections, and planning and co-ordination, would continue to function as at present. The board approved this recommendation and requested the president to appoint two co-ordinating committees for the coming year for the professional and administrative groups which are to be composed initially of the following committees:

Professional Group

Code of Principles of Professional Conduct
Registration of engineers
Education
Student branches
Management
Edison Medal
Charles LeGeyt Fortescue Fellowship
Lamme Medal
Award of Institute prizes

Administrative Group

Membership
Constitution and bylaws
Headquarters
Board of examiners
Transfers
Publicity
Members-for-Life

The chairmen of these two co-ordinating committees and of the four technical co-ordinating committees are to be ex-officio members of the committee on planning and co-ordination.

Individual members of the committee carried on special assignments arising from suggestions received from officers and members. To cite but one example, the question of changing the present geographical boundaries of the Districts was given thorough study in collaboration with the District vice-presidents, and it was concluded not to recommend any substantial changes for the present.

To facilitate arrangements and insure more adequate accommodations for the four general meetings held each year, a schedule of dates and locations through the year 1950 has been adopted by the board. District meetings likewise have been scheduled through 1948.

The committee has endeavored to keep the membership currently and more fully informed of its activities through the columns of *ELECTRICAL ENGINEERING* than is possible in this annual report.

UNITED STATES NATIONAL COMMITTEE OF THE INTERNATIONAL ELECTROTECHNICAL COMMISSION

The United States National Committee of the IEC held its annual meeting, November 8, 1946, and elected the following officers:

President—L. F. Adams.
Vice-president—P. H. Chase.
Vice-president and treasurer—H. S. Osborne.

In the election of Mr. Adams as president of the USNC, a tradition was broken. Over its long history the presidents of the USNC always have been from the general interest group. Mr. Adams is the first president from the manufacturing group. In the early days of the USNC and the IEC, the work was concerned primarily with the fundamental electrical problems of units, measurement, and the basis for rating electric machinery. In the years immediately preceding the war the work became more and more the standardization of the methods of rating and testing electric machinery and associated problems. It appears that this trend will continue as the work is resumed.

A meeting of the council of the IEC was held in Paris in July 1946. Consideration was given at the meeting of the IEC council to the question of affiliation with the proposed new International Organization for Standardization (ISO) and a favorable recommendation was made on affiliation, provided that certain conditions are met. A final decision on affiliation was deferred until the constitution of the ISO could be approved by the member countries and its organization set up.

Professor L. Lombardi tendered his resignation as president of the IEC, and a new president was elected. E. Uytborck, president of the Belgian Electrotechnical Commission, succeeded Professor Lombardi as IEC president. Emile Brylinski, honorary president of the French Electrotechnical Committee, was elected honorary president of the commission. As Lord Mount Edgcumbe had tendered his resignation as honorary secretary of the IEC, Doctor P. Dunsheath of Great Britain was elected honorary secretary.

A new committee of action of the IEC (executive committee) was designated, to consist of the president, the honorary secretary, and representatives from Czechoslovakia, France, Sweden, Switzerland, the United States, and the Union of Soviet Socialist Republics.

As to the business of the IEC itself, the opinion of the council was that all emphasis should be placed on getting action on technical projects and that it would not be expedient now to undertake a revision of the constitution or of the procedures of the IEC which have grown up in the course of the commission's work. The status of technical projects was reviewed. The following new advisory committees were nominated: extra-high voltages, number 30; flameproof enclosures, number 31; fuses, number 32;

and capacitors for power systems, number 33.

A review of the advisory committees was made, and the work was divided into three categories:

1. Very urgent work on which meetings of the responsible advisory committees should be held within a year.

Number 6—Lamp cap and holders
Number 8—Voltages
Number 30—Extra-high voltages
Special international committee on radio interference (CISPR)

2. A much larger group of projects which were sufficiently urgent to require a meeting of the advisory committees within two years.

Number 2—Rotating machinery
Number 9—Electric traction equipment
Number 12—Radio communication
Number 16—Terminal markings
Number 17—Switchgear
Number 22—Electronic devices
Number 24—Electric and magnetic magnitudes and [redacted]
Number 25—Letter symbols
Number 28—Co-ordination of insulation

3. Remaining projects which would be started as soon as required. These include IEC projects not listed.

The IEC committee of action met in London, October 14, 1946, but no further action was taken on the question of affiliation with the ISO. It is expected that a meeting of the IEC council will be held in Geneva, Switzerland, in June 1947, and technical meetings have been proposed for September 1947, in Zurich, Switzerland.

Standards

STANDARDS COMMITTEE

The war period necessarily was accompanied by a reduction in many of the Institute activities including those of the Standards committee. However, every effort was made to carry forward its various projects with a minimum of interruption, and, because of the splendid co-operation of its members and of the technical committees of the Institute, very few of the vital standards projects were wholly interrupted. Since the end of the war, the shortage of man power and testing facilities, so necessary to standards work, has not been substantially ameliorated, but it has been possible to revive practically all of the dormant projects and to make some progress during this year in bringing them to completion.

The partial inactivity during the war naturally resulted in the accumulation of subjects—both in the AIEE and the ASA—which has made the work of reorganization and reactivation of many committees more onerous than it otherwise would have been. Casualties in committee personnel, due to death, and retirement, and other reasons, necessitated extensive changes in many committees of the Institute and in ASA committees to which the Institute appoints representatives.

The Standards committee now consists of 16 executive members plus the chairmen of all technical committees, who serve as ex-officio members. The executive group is chosen to secure a reasonable continuity in membership. This is very desirable, as the group is responsible for the approval of Institute Standards, and the necessary familiarity with Institute standard activities cannot be obtained during a short term of membership.

The number of Standards, reports, and so forth issued during the year is no indication of the amount of work carried on by either the Standards committee or the technical committees. It is believed that this year's production is a very creditable performance.

During the year the following Standards and reports on proposed standards and codes have been approved: Revision of Standard 1, "General Principles Upon Which Temperature Limits Are Based in the Rating of Electric Machines and Apparatus," which revision takes into account suggested temperature limits for class *H* insulation (the new silicone materials); number 6, "Report on Standards for Pool Cathode Mercury-Arc Power Converters;" number 32, "Standards for Neutral Grounding Devices;" revision of number 40 "Standards for Electric Recording Instruments;" "Master Test Code for Resistance Measurements;" number 43, "Report on Recommended Practice for Insulation Testing of A-C Rotating Machinery."

A progress report by the committee on air transportation indicates a rapid development of the many aeronautical projects, both standards and codes, undertaken during war years. The following have reached the publication stage: number 700, "Standard for Aircraft D-C Apparatus Voltage Ratings;" number 800, "Test Code for D-C Aircraft Machines;" "Guide for Aircraft Electric Systems." The progress made in the field is particularly commendable when it is realized that it has been necessary to provide for the many changes in committee personnel brought about by the industrial shift from war to peace.

Special mention may be made of two subcommittees which are engaged in preparing reports on controversial matters. The subcommittee on sign of reactive power published an article in *ELECTRICAL ENGINEERING* which has provoked a very large amount of discussion, and it is not anticipated that agreement will be reached on its recommendations very soon. The subcommittee on conduction in stationary contact surfaces, after several years' work, has prepared a report which has been accepted by the Standards committee for the information of technical committees only. The controversial points deal with temperature rise recommended for various types of contact.

The subcommittee on applications of statistical methods continues to be active, and it is planning for the enlargement of its projects and for the presentation of educational and specialized papers.

Among ASA activities in which the Institute is interested, special mention should be made of *C42*, "Definition of Electrical Terms." The committee has been inactive since 1941 following the publication of the present American Standard. It now has been reorganized completely into 17 subcommittees; some of these already have begun work. It is evident that the work of *C42* will be concerned largely with the broadening of scope and the consequent addition of many new definitions.

Technical Committees

COMMITTEE ON AIR TRANSPORTATION

The committee on air transportation held one meeting of the entire committee during the administrative year. This meeting was a 2-day session held in Cleveland, Ohio, September 23 and 24. On the afternoon of September 24, the committee met jointly with committee *A-2* of the Society of Automotive Engineers. All of the sessions were well attended, and considerable progress was made in connection with the standardization activities of the committee.

At the end of the year the status of subcommittee work is as given in the following paragraphs.

Aircraft Electric Systems. This subcommittee has been re-organized. A preliminary draft of the "Aircraft Electric Systems Guide" has been printed and submitted to the Standards committee for assistance in circulating the material throughout industry for criticisms, suggestions, and contributions. The guide report is not as yet sufficiently complete for publication as a "Report for Trial Use," but it contains a great deal of valuable information, and much good will be accomplished by wide dissemination of the preliminary draft.

Aircraft Electric Rotating Machinery. This subcommittee has completed a proposed test code for d-c aircraft machines. This was published for trial in March 1947 as "AIEE Report 800."

At the present time this subcommittee is engaged in a new project under the general subject of "Rating Standards of D-C Aircraft Generators."

Aircraft Electric Control, Protective Devices, and Cable. This subcommittee has been reorganized, and has completed a report on aircraft wire and cable originally requested by the SAE committee *A-2*. The first meeting of the reorganized committee was held January 21. The present program consists of three items:

1. Determination of the interrupting capacity circuit breakers.
2. Test code for circuit interrupting devices.
3. Test code for voltage regulators.

Work is under way on all of these projects but has not progressed sufficiently for a detailed report at this time.

Joint Subcommittee (Air Transportation and Electric Machinery) on Carbon Brushes. This subcommittee met in New York, January 29, and also met in conjunction with the d-c machinery committee, January 30. Considerable progress has been made toward the objective of this committee: the formation of an AIEE test code for the evaluation of carbon brush performance on all types of commutators and collector rings to provide for improved specifications and standards for carbon brushes used on electric machinery.

Subcommittee for Altitude Ratings. This subcommittee is developing an AIEE Standard outlining the basic principles of altitude rating of electric machinery. Substantial progress has been made in accumulating material for this project, particularly for the range of sea level to 50,000 feet. The Naval Research Laboratory, the Bureau of Aeronautics, the Army Air Forces, and the Bureau of Standards are co-operating with industry members of this subcommittee in accumulating basic data. An important object of this work is to obtain better correlation of altitude chamber test results obtained in high-altitude flying.

A final draft of AIEE 700, "Report on Aircraft D-C Apparatus Voltage Ratings," was approved by the board of directors.

The committee on air transportation sponsored a conference on aircraft electrical safety during the winter meeting. Approximately 200 engineers from all phases of aviation work participated in the program. The minutes of the meeting are available on application to headquarters.

The committee on aviation and airport fire protection of the National Fire Protection Association has suggested that the two committees co-ordinate their work, insofar as electrical fires on aircraft are concerned. Sentiment of the members of the committee on air transportation is very much in favor of such co-operation, and arrangements are being worked out to the mutual satisfaction of the two committees.

Technical papers were considerably below normal volume during the year. Personnel shifts are still prevalent in the industry and in the military services, and few engineers can find time for the preparation of papers. Plans are, however, under way now for strong air transportation sessions at the Pacific general meeting in August, and the Middle Eastern District meeting in September.

COMMITTEE ON AUTOMATIC STATIONS

The committee has sponsored two technical program sessions during the last year. At the summer meeting, ten papers on the subject of automatic control of capacitors, synchronous condensers, air switches, and single pole switches were presented at the conference session. At the winter meeting, the subjects of automatic control for capacitors and automatic control of air switches were presented at a technical session. Much interest was indicated in these subjects by the lively discussion which followed their presentation. Other interesting subjects are being considered for future presentation.

The committee met twice during the year with very good attendance records and has been represented at each general session of the technical program committee. The membership, individually and through its officers, has taken an active interest in the proposed technical program committee reorganization plan.

One working group has completed a report on the study of d-c polarity on device coil corrosion. This report indicates that all cases of coil corrosion have occurred on equipments in which coils were connected directly to the positive control bus. It is concluded that connections should be made to the negative bus in order to prevent this corrosion. The report is being referred to the standards committee for consideration and final disposition.

Another working group is continuing its investigation of a-c versus d-c tripping schemes. It is expected that, in co-operation with other committees, definite solutions to tripping problems can be developed, especially as applied to small isolated stations.

The committee has been represented actively on various other committees and subcommittees.

COMMITTEE ON BASIC SCIENCES

With the ending of the war, the work of the committee on basic sciences has increased, as material for publication becomes less restricted.

The greater activity of the committee is exemplified in the formation of subcommittees on new energy sources, large scale computing devices, applied mathematics, and electric circuit theory, together with representation on the joint subcommittee on servomechanisms and on the newly formed committee on nucleonics.

At the 1947 winter meeting, conferences were held on applied mathematics, new energy sources, large scale computing devices, and servomechanisms. A session on general basic science topics completed the most active technical meeting in the history of the committee. Attendance at the conferences was among the highest at winter meeting sessions, a factor which encourages the committee to continue these types of conferences.

Although only one conference is scheduled for the 1947 summer general meeting, future plans call for continued activity in the several fields of the present subcommittees, with the possible formation of additional subcommittees as these are warranted. With the scope of the committee on basic sciences crossing all technical fields, it is planned to insure that no areas are being left uncovered.

Co-operation with associated technical committees and outside organizations also is being developed. The subcommittee on applied mathematics maintains contact with the American Mathematical Society to develop better uses of mathematics to the solution of engineering problems. Co-operation between ASA Sectional Committee *C-42*, Definitions of Electrical Terms, is assured through the chairmanship of subcommittee 1 of ASA *C-42*, together with several members of the committee on basic sciences, also members of subcommittee 1.

Although the committee is dispersed widely geographically and, hence, is limited in the number of meetings which can be held during the year, excellent co-operation of the membership has been possible through the subcommittee method of operation and voluminous correspondence between the members. A meeting of the committee was held during the winter meeting, January 28, 1947, at which time plans for future technical meetings were considered.

COMMITTEE ON COMMUNICATION

This committee has continued to bring to the Institute papers dealing with many phases of the very broad and continually expanding field of communications. Among the subjects covered during the past year were television; systems for microwave radio in the fields of telephone, telegraph and television; military communications; rural telephone facilities; new telephone switching systems; several phases of telegraphy; new developments in communication components, such as thermistors and filters; progress in the field of ocean cables; and gas pressure protection for telephone cables.

The committee sponsored full sessions at all of the general meetings. The summer meeting in Detroit included papers on military communications, properties and uses of thermistors, a method for transmission rating of telephone systems, and improved types of mica capacitors for communications equipment. At the Pacific Coast meeting in Seattle, papers were presented on the status of television, compression and expansion of telephone signals, power line carrier, and carrier shift telegraphy. The winter meeting in New York included four communications sessions:

1. A session on television covered the various elements in a television system, that is, the broadcasting station, receivers, network facilities, and transmission from remote pickups. It also included a review of color television and an interesting demonstration of television cameras and receivers.

2. A rural telephone symposium covered four methods of providing rural service: telephone lines, joint power and telephone lines, carrier on power conductors, and radiotelephone.

3. A conference on testing telephone receivers and transmitters included talks by representatives of many industrial and research laboratories and was followed by questions and discussions from the floor.

4. In the session on communications components and techniques a new dial switching system was described; arrangements for protecting telephone cables by means of gas pressure were outlined; and new methods of operating telegraph over wire lines, radio, and ocean cables were discussed.

Every effort has been made to assist District meetings in presenting good communications programs. Papers solicited and reviewed by the committee on communication were made available to District meetings in San Antonio, Tex.; Indianapolis; and Worcester, with the chairman of the committee presiding at the communication session in Indianapolis.

Continued emphasis was placed on papers for publication, as contrasted with conference papers, so that the results of the committee's activities would be made available to the whole Institute membership and not be limited to the relatively few who can hear the presentation. During the year, 20 papers and reports sponsored by the committee were published in *ELECTRICAL ENGINEERING* or in *TRANSACTIONS*, and many more have been recommended for future publication.

Meetings of the whole committee were held in June, September, and January, and subcommittees have met on numerous occasions. Eight subcommittees have been active during the year: testing of telephone transmitters and receivers, underwater sound developments, rural telephone facilities, television, radio communication systems, modulation methods, power line carrier for power company communications, and hearing aids.

The committee's activities have been directed primarily toward serving well that large segment of the Institute's membership whose primary interest is communications by keeping them abreast of developments in their field. In addition, it has tried to present information on communications which would be of general interest to those whose activities are in other fields of engineering.

DOMESTIC AND COMMERCIAL APPLICATIONS COMMITTEE

The activities of this committee during the past year have been carried on through five subcommittees covering the following fields: electric appliance design, electrical hazards to farm animals, farm applications, load characteristics, and wiring. Following is a brief résumé of what is being done by each of these groups.

The electric appliance design subcommittee is gathering comprehensive data on the many trial installations of heat pumps now in existence in several different parts of the country. Plans are being made for a technical session on the general subject of heat pumps for the 1948 winter general meeting.

During the past year, the electrical hazards to farm animals subcommittee has continued to gather data. Consideration is being given to the preparation of an educational pamphlet on the elimination of such hazards that could be distributed widely among county farm agents, rural electrical inspectors, and others who could benefit from the information.

The farm applications subcommittee, in conjunction with numerous other organizations, sponsored the first National Farm Electrification Conference in November 1946. Because of the success of the initial conference, the sponsoring bodies have decided to continue the conference as an annual affair. This subcommittee will continue to co-operate with the other groups.

Recognizing that distribution engineers have need for accurate information on load characteristics, and that most of the data available are now quite old, the load characteristics subcommittee has been endeavoring to assemble more recent test and survey data on residential electrical load characteristics, generally, as well as data on specific appliances and applications, such as automatic washing machines, electrical househeating, and heat pumps.

The principal activity of the wiring subcommittee during the past year has been co-operation with the committee on industrial applications in the preparation of recommendations for interior wiring design for public and commercial buildings.

COMMITTEE ON ELECTRIC MACHINERY

A meeting of the committee was held in New York during the winter meeting, January 1947. Each of the subcommittees presented a report on its activities during the year, and then considerable discussion took place regarding the reorganization of the technical committees proposed by the technical activities subcommittee of the committee on planning and co-ordinating. This proposal included, among other things, the grouping of the various technical committees into four principal groups, and then each of the present technical committees was asked how it should be split up. The committee on electric machinery expressed a desire to aid in committee activity in any way that would benefit the industry but it had insufficient knowledge to offer suggestions at the time and suggested that a definite plan be proposed. Since that time, various suggestions have been made, but no definite action in dividing the committee has yet resulted.

During the winter meeting, the five active subcommittees held meetings to review their activities, consider papers available for future meetings, and to plan for the future.

A report on "Insulation Resistance Testing of A-C Rotating Machinery" prepared by the insulation resistance subcommittee was issued by the Institute during the year. A report for insulation testing of d-c machinery is being prepared.

The induction machinery subcommittee is continuing the sponsorship of temperature tests of motors from which it is expected that better rating data and standards can be determined.

The transformer subcommittee has sponsored for several years a co-operative laboratory test on aging of class *A* insulation, and a preliminary report is being prepared for the summer general meeting.

The afore-mentioned three subcommittees, the synchronous machinery subcommittee, and the d-c machinery subcommittee have sponsored papers for the various sessions.

The committee as a whole conducted one session at the Indianapolis meeting in October, three sessions at the winter meeting, and is planning on two sessions at the summer general meeting. In addition, some electric machinery papers have been presented at District meetings.

COMMITTEE ON ELECTRIC WELDING

A meeting of the committee was held November 21, in Atlantic City, N. J., during the National Metal Congress. Plans for the winter meeting and for the summer general meeting were discussed. The committee was brought up to date on the latest recommendations of the technical activities subcommittee. It was the consensus of this committee that these recommendations when carried out would result in definite improvements. It was also the committee's thought that the new publication policy would be of greater benefit to the membership.

Two subcommittees were appointed; one on resistance welding, and the other on arc welding. The need for assistance by members of this committee to the Sections was emphasized, and their co-operation was requested. It is understood that the Michigan Section at the request of one of this committee's members is considering the formation of a technical group on electric welding. It was reported that the formation of ASA Committee *C52* was complete and work was progressing.

This committee sponsored one conference session on power supply for resistance welding at the winter meeting, and also one technical session on resistance welding. Five conference papers were presented at the conference session, and four technical papers were presented at the technical meeting. It also is planned to hold a conference session at the summer general meeting on power supply for resistance welding. It is the intention to rely principally upon members from Canada for these papers. It also is planned to hold a meeting of this committee at the same time.

COMMITTEE ON ELECTROCHEMISTRY AND ELECTROMETALLURGY

A meeting of the committee was held January 30, 1947, during the winter meeting. At the January 30th meeting of the board of directors, a change of name for this committee was approved. The name is to be the "chemical, electrochemical, and electrothermal committee." As a means of covering the field as visualized to be within this committee's scope, seven subcommittees have been named, covering different aspects of the technical field, and the chairmen and members of all but one have been either appointed or considered.

Subcommittee on Metallic Rectifiers. A technical session on dry-type rectifiers was held at the winter meeting, January 27, 1947. "Proposed Standards for Metallic Rectifiers" was completed during the year. "A Bibliography on Metallic Rectifiers and Their Principal Applications" was completed during the year.

Subcommittee on Voltage Transients in Arc Furnaces. A report is in process.

Subcommittee on Batteries, Battery Forming and Charging. This subcommittee was formed and personnel appointed. It is expected to become active in 1947.

Subcommittee on Cathodic Protection. This subcommittee was formed and personnel appointed. It is expected to become active during 1947.

Subcommittee on Petroleum, Refining and Production. A chairman has been appointed and is at work on personnel. It is expected to become active during 1947. A joint session with American Petroleum Institute at its annual meeting is planned.

Subcommittee on Electrolytic Processes. This subcommittee is formed and active. A group of conference-type papers by operating personnel on this subject has been arranged for the summer general meeting.

Subcommittee on Arc and Electrothermal Processes. No chairman has been appointed as yet. Incomplete personnel.

COMMITTEE ON ELECTRONICS

The work of the committee has been carried on during the past year principally through 15 subcommittees. A meeting of subcommittee chairmen held in October 1946 served to crystallize the plans and co-ordinate the work of these subcommittees. In addition to the general meeting of the committee, which was held during the winter meeting, there have been meetings of many subcommittees devoted to the special tasks of these groups.

Two technical sessions, one on electronics and another on electronic instruments, and a conference on some new electronic methods and devices were held during the winter meeting. An electronics session and a conference on rectifiers are planned for the summer general meeting. During the calendar year 1946, *ELECTRICAL ENGINEERING* contained 31 articles including important electronic material. The activity of the committee and its subcommittees has contributed substantially to this result.

The subcommittees have been engaged in the following activities.

Electronic Heating. This subcommittee has rendered valuable service to the Federal Communication Commission in the study of radiation from high-frequency heating equipment by collecting data on radiation levels and by presenting the professional point of view to the commission at a public hearing, December 18, 1946. It also has been concerned actively with methods of rating electric heating equipment and with the problem of safety from electric shock at the frequencies used for electric heating.

Electronic Instruments. A technical session on electronic instruments was held during the winter meeting with a program of five papers. Several additional papers are in preparation. A survey of instrument manufacturers is in progress to determine the need for electronic tubes with special characteristics for use in electric instruments.

Electronic Papers Solicitation and Section Contacts. This subcommittee effectively has encouraged and solicited the publication of papers dealing with electronic subjects. A policy of distributing electronic papers to other committees, which sponsor sessions where the electronic application is appropriate, has been continued, and this policy has been effective in broadening the interest in electronic subjects.

A conference on some new electronic methods and devices was held during the winter meeting. This was a continuation of a series of similar conferences which have been very successful.

Films, speakers, and technical information on electronic subjects have been provided liberally to the Sections for technical meetings through this subcommittee.

High-Frequency Conductors, Cables, and Connectors. This subcommittee has expanded its membership to cover the large field assigned. Co-ordinating contact has been established with the Radio Manufacturers Association, and surveys are being prepared on "Television Camera Cables," "Power and Current Ratings of Coaxial Cables," "Test Methods for Coaxial Cables," and "Hookup and Set Wire."

Hot-Cathode Electronic Power Converters. This subcommittee, which was organized during the year, will be engaged actively in the preparation of standards. A group well qualified for this task has accepted membership, and work will start with a meeting planned for May 1947.

Pool-Cathode Electronic Power Converters. This group has continued work on a bibliography for electronic power converters. The work on hot-cathode power converters which was initiated in this group has been set up as a separate subcommittee.

A working group has been organized to prepare a report on "Protection of Power Converters." Another group is working on a report on "New Developments in the Design and Application of Electronic Power Converters in Europe." A conference on operation of mercury-arc rectifiers is planned for the summer general meeting.

Liaison With Other Groups. The co-ordination of electronics committee work with the Institute of Radio Engineers and the Joint Electron Tube Engineering Council has operated smoothly through the liaison subcommittees of the committee on electronics. In several instances, joint subcommittees have been formed.

Other Technical Subcommittees. The committee includes technical subcommittees on electron tubes, electronic nomenclature and definitions, electronic precipitation, electronic standards, and X-ray tubes. These subcommittees have been active during the year in the fields assigned. The subcommittees on electronic control and electronic welding have been discontinued, and these fields will be covered by other AIEE committees.

The subcommittees on electronic heating and pool-cathode electronic power converters have been transferred to the status of AIEE technical committees.

The committee closes the administrative year with 11 active subcommittees as follows: electron tubes; electronic instruments; electronic papers solicitations and section contacts; electronic precipitation; electronic standards; high-frequency conductors, cables, and connectors; liaison with IRE; liaison with JETEC; nomenclature, definitions, letters and graphical symbols; hot-cathode electronic power converters; and X-ray tubes.

COMMITTEE ON INDUSTRIAL CONTROL DEVICES

This committee has taken an active part in the planning of the reorganization of the technical committees of the Institute. Under the present plan, the committee's scope and activities will become broadened to a considerable degree, and its membership will be expanded to give the users of industrial control equipment a broader place in its activities.

The subcommittee on industrial electronic control has discussed its field of activities with the corresponding subcommittee of the committee on electronics to avoid a duplication of work. It is also in contact with other engineering groups in a joint effort to promote satisfactory standards, covering definitions, test codes, and recommended practices for electronic control equipment.

The subcommittee on test codes for industrial control devices has analyzed a number of possible objectives, and is now charting a definite course of action.

The work on a bibliography of electrical control has progressed excellently, and the committee hopes eventually to publish a rather complete bibliography on this subject.

The joint subcommittee on servomechanisms, sponsored in conjunction with the committees on basic sciences and instruments and measurements, had a very active year and sponsored a technical session at the summer meeting and another at the winter meeting. An effort is being made in papers and otherwise to present the basic theory and mathematical treatment in a manner which will promote the industrial applications of this useful tool.

The committee sponsored a technical session at the summer meeting and another at the winter meeting. The sessions were well attended, and there is reason to believe that they filled a definite need. The committee also has solicited papers for the 1947 summer meeting, and expects to sponsor a session at that time. Committee meetings were held in conjunction with the summer and winter meetings.

COMMITTEE ON INDUSTRIAL POWER APPLICATIONS

At the 1946 summer meeting, two full sessions were sponsored by the committee, to which members of the Detroit Industrial Electrical Engineering Society were invited. These sessions featured industrial voltage requirements (a subcommittee report), protective devices for and insulation breakdown in industrial plants, distribution in nonindustrial buildings, induction heating, application to the rubber industry, and electronic printing control. A committee luncheon also was held during this national meeting.

For the 1947 winter meeting, the committee continued to foster its policy adopted last year of highlighting one particular industry at each major AIEE meeting (January 1946—machine tools) by holding a most successful session on applications of electric power in the textile industry. This session included four well-co-ordinated papers written by both manufacturers and users, and plans are being made to combine the papers as one report, as a special publication. This was the first time in AIEE history that a session was devoted to the problems of electric equipment in the textile industry. Reports on other industries may be treated similarly as they are covered at national meetings. For instance, two sessions on the pulp and paper industry will be sponsored by this committee at the summer general meeting.

At the winter meeting, the committee also sponsored a conference on industrial voltage requirements (including subcommittee report) along with a discussion of voltage regulation for industrial systems. A third session on industrial instrumentation and control was sponsored jointly with the committee on industrial control devices.

During the winter meeting, the committee and invited guests held a luncheon at the Hotel Commodore, at which a spirited and most constructive discussion took place on the recent formulation of the industry group of technical committees. Considerable enthusiasm was expressed on the formulation of definite technical committees to stimulate the study of applications of electricity to specialized industries.

The subcommittee on interior wiring design of commercial buildings is formulating a report under the same name to be published as a recommended practice. This will be a companion report to "Power Distribution in Industrial Plants," which was prepared by the committee on industrial power applications.

By action of the board of directors, in January 1947, the subcommittee on machine tool and processing industries was raised to the status of a full technical committee (machine tools, material processing, and fabrication). Also the committee on industrial power applications now becomes industrial power systems, with a scope involving generation, transmission, and distribution of electric power within an industrial plant.

COMMITTEE ON INSTRUMENTS AND MEASUREMENTS

Meetings of the committee on instruments and measurements, which now consists of 36 members, were held November 14, 1946, and April 11, 1947. The committee has handled more than 42 papers, and has been active in sponsoring numerous sessions at technical meetings. Sessions on instruments and measurements were held at the summer and winter meetings. Papers at these sessions covered a wide range of instruments and measurements applications, including compensation of ammeters and voltmeters for frequency variation, a functional analysis of measurements, an a-c network analyzer, high-vacuum leak testing with the mass spectrometer, airborne magnetometers, ignition crest voltmeters, long-scale indicating instruments, measurements at 10,000 megacycles, and a polyphase thermal-demand meter.

The foregoing list of subjects emphasizes the wide scope of measurements, and indicates the desirability of close co-operation between the committee on instruments and measurements and many of the other technical committees in the Institute. Such co-operation has taken place through the formation of four joint subcommittees with the committees on automatic stations, electronics, basic sciences, and industrial control devices. Several of these joint subcommitttees have sponsored sessions at the summer and winter meetings, as reported in the following material.

Work on a standard on electric recording instruments and on master test codes for resistance measurements and for temperature measurements has been completed by subcommittees. These standards have been submitted to the Standards committee with the recommendation that they be published for one year trial use with subsequent adoption as AIEE Standards.

Activities of the remainder of the 15 subcommittees have been as follows.

Subcommittee on Revision of Standard 4 (Measurement of Test Voltage in Dielectric Tests). Revisions of the membership have been completed, and work is started on the problem of surge voltage measurements at intervals of less than one microsecond. New material on voltage measurements with direct current and high frequencies is to be added.

Subcommittee on Watt-Hour Meters. This subcommittee is working on rectifying the differences between the definitions in the "Code for Electricity Meters" and those in the ASA *C42* definitions.

Subcommittee on Definitions. Definitions for the next revision of ASA *C42* are being considered by this group.

Subcommittee on Revision of C39 (Electrical Indicating Instruments). The method of describing the accuracy of instruments is being considered by this group, and it is working closely with the ASA *C39* sectional committee in revision of that standard.

Subcommittee on Dielectric Measurements in the Field. A bibliography and a working outline of a report on progress in the art of dielectric measurements in the field have been completed, and preparation of the various sections of the report has been assigned to the members of the subcommittee.

Subcommittee on High-Frequency Measurements. A table of standard frequency ranges and designations referred for recommendation by the Standards committee was considered by this group. The subcommittee recommend that a joint subcommittee be set up to consider the matter, and the joint subcommittee is now active.

Subcommittee on Instrument Transformers. This subcommittee will continue its efforts to arrange the material in ASA *C57* pertaining to instrument transformers in proper form for separate publication, when all the ASA material including revised and additional definitions is available.

Subcommittee on Marking of Varmeters and Related Instruments. This subcommittee awaits action by the Standards committee on the sign of reactive power before proceeding with its consideration of a standard method for marking varmeters.

Joint Subcommittee on Telemetering. This joint subcommittee is engaged in revising the 1941 AIEE report on "Telemetering Supervisory Control, and Associated Circuits." The subcommittee plans to hold a conference session on telemetering at the summer general meeting.

Joint Subcommittee on Servomechanisms. The initial activity of this new joint subcommittee was the sponsoring of a session at the summer meeting. Sessions also were sponsored at the winter meeting and the North Eastern District meeting, and one is planned for the summer general meeting in Montreal. This subcommittee has set up broad objectives as follows: (1) to solicit papers on theory, (2) to stimulate work on the preparation of papers on components, (3) to undertake a program to assist with the education of the AIEE membership as to the fundamentals of this subject, and (4) to formulate plans for unification of terminology.

Joint Subcommittee on Electronic Instruments. This new joint subcommittee sponsored sessions at the summer and winter meetings. It is making a survey of instrument manufacturers to determine the need for electronic tubes with special characteristics for use in electronic instruments.

Joint Subcommittee on Frequency Bands and Designations. As reported earlier, this new joint subcommittee is considering a table of standard frequency bands and designations. A report to be published in *ELECTRICAL ENGINEERING* is in preparation.

COMMITTEE ON LAND TRANSPORTATION

Two well-attended meetings of the committee were held during the past year one in June 1946, and one during the winter meeting in January 1947. The following activities were discussed and organized at these meetings.

Technical Meetings. Three transportation sessions were held at the winter meeting. A light traction session, included a special address by General C. P. Gross, chairman, New York Board of Transportation; two technical papers describing new car equipment for the New York subways; and one on trolley coaches. A second session included a paper on the development of current collectors for high speed railway service, two on PCC street car subjects, and one on silicone insulation for railway motors; and the third session included five papers on electric equipments for Diesel-electric locomotives. These sessions all were well attended. A transportation session has been scheduled for the summer general meeting, including five papers.

Subcommittee Activities. A subcommittee has been engaged in a review of AIEE Standard 16, "Standards for Electric Railway Control Apparatus." A meeting was held January 28, 1947, and another is scheduled for May. Definite progress is being made by this subcommittee, and it is hoped that a report can be submitted within the next year.

Another subcommittee is engaged in gathering and tabulating heavy traction electrification data. Some progress has been made in the collection of data on overhead catenary systems, and work is in progress to begin tabulations on locomotives and on power supply equipment.

COMMITTEE ON MARINE TRANSPORTATION

Early in the current administrative year a request was received by the committee from United States Coast Guard (Technical Division) to consult with them for the purpose of reviewing and commenting on their proposed regulations for electrical work on shipboard.

At its October 1946 meeting, the committee carefully considered this request. It was apparent that Coast Guard regulations follow closely the recommendations published in AIEE Standard 45, 1945 revision, with deletions and additions based on Coast Guard's past experience in administering Standard 45. The committee decided to review the proposed regulations giving particular attention to each item. Comments and recommendations resulting from the review of each item as mutually agreed on are to be accepted by the Coast Guard and, if recommendations of Standard 45 are affected, revisions to be noted and made. The committee, realizing that the review would require considerable time and effort, decided to hold monthly meetings of two days each, and five such meetings were held. The last meetings were held May 8–9.

It is believed that considerable benefit has accrued from this review both to the Coast Guard and the committee.

The mass of comments and recommendations compiled during the review has been referred to the committee's editing subcommittee for co-ordination for eventual submission as a revision of Standard 45. It is expected that the revision will be ready for appropriate action early in the coming administrative year.

The committee's activities during the past year have been confined almost wholly to the afore-mentioned review.

Thanks and appreciation have been expressed mutually between the committee and the Coast Guard for consideration and assistance to and from both.

The committee members have rendered most valuable service all during this review. Participating attendance for the 11 required meetings has averaged 85 per cent.

COMMITTEE ON NUCLEONICS

There has been no activity of the committee during the current year because of delays in organization and planning. The committee was authorized in October 1946; a nucleus of committee members suggested in January was appointed by President Housley. Further appointments have been suggested for the coming year.

The first committee meeting is scheduled to be held at the summer general meeting, at which time plans for this activity will be discussed.

COMMITTEE ON POWER GENERATION

Two meetings of the committee were held during the fiscal year, in which reports of the subcommittees were considered. In addition, the committee sponsored one session at the summer meeting at which two papers on hydroelectric stations and two on excitation systems were presented. At the winter meeting, two sessions were sponsored, one presenting four papers on hydroelectric stations and related problems, and the second a conference on interconnected systems. All sessions were well attended, indicating a wise selection of program material.

Specific committee activities are typified by the subcommittee reports which are briefed in the following paragraphs.

Hydroelectric Systems. Continued interest in various phases of hydroelectric station operation warrant presentation of three more papers on this subject at the summer general meeting in Montreal. This will be the fourth session including hydroelectric papers since their initial presentations sponsored by the committee at the winter meeting of 1946. At this summer's session, an additional paper on German utility experience during the war will be included.

Interconnected Systems. Following the well-received conference session on this subject at the winter meeting which, was marked by a large attendance, it is gratifying to report another program of three to four papers is available for future meetings. These probably will be presented during the fall of the coming year.

Grounding Practices. This working group is organized to collect data on present-day practices and trends of system grounding, including both generating stations and transmission systems classified as to size, voltage, and mileage. It is intended to summarize (1) the bases used in grounding-method selection (2) operating experience (3) grounding devices used. Changes in grounding practices since 1931 also will be analyzed.

Questionnaires have been sent out, and returns have been received from 434 systems, including over 960 generating units aggregating more than 33,000,000 kva. In the transmission system grounding section, some 510 systems are covered, involving more than 100,000 miles of transmission circuit. The report is expected to be ready for presentation this coming year.

Excitation Systems. This subcommittee, originally organized to prepare programs on this subject, was assigned the added task of studying the standardization of excitation systems. The group now is gathering data on definitions and practices which will be presented in a report.

At the present time two papers are available for future meetings, one on effect of excitation systems on large-system stability, and another on electronic exciters for synchronous generators.

Prime Mover Governing. This joint AIEE–ASME Committee on Prime Mover Speed Governing Specifications will complete a draft of governing specifications for steam turbines by November 1947. It is expected to have a draft of hydroelectric-unit governing specifications ready by the summer of 1947.

Probability. This subcommittee was organized to prepare a program of papers on the subject of probability theory and its application to electric power systems planning. Several papers have been solicited, and it is expected a program will be organized in the near future.

Power Generation Report. A committee report covering the progress in power generation during the years 1940–46 has been prepared by the subcommittee and will be presented for approval of the committee during the summer of 1947.

COMMITTEE ON POWER TRANSMISSION AND DISTRIBUTION

A meeting of the committee was held December 12 and 13, 1946, which 36 members and guests attended. The subcommittees made reports on their activities, followed by a general discussion of the subjects and suggestions for future work. At the completion of the reports of committees, several members made reports on activities within their respective companies during the war period, on future plans, and technical subjects. Arrangements are being made to have them abstracted for publication in *ELECTRICAL ENGINEERING*, and to make them available to Institute members who may be interested. These reports covered such subjects as: Transmission system practices in foreign countries, 500-kv test line, bundle conductors, the era of higher distribution voltages, increased loading of electric power plant, obsolescence, the cost of losses, new distribution substation developments, lightning—effect on buried cables, banking of distribution transformers, increasing transmission line capacities, a-c network calculator laboratories, peanut substations, and transpositions in power lines—their advantages and their hazards.

Technical Meetings. At the winter meeting, the committee sponsored two sessions at each of which four papers were presented. One of these sessions was a symposium on lightning, which dealt with lightning surges at substations, photographic study of lightning, lightning arrester discharges, and burning of wood structures by leakage circuits. The other session was of a general nature covering reporting on weather conditions as an aid to power companies, line stability, internal corona discharges in insulated cables, and radio noise on 230-kv lines.

Subcommittee Activities. The general systems committee is investigating the following subjects: (1) evaluation of power losses throughout the power systems and their effect on all equipment from the generator to the user; (2) effect of surges on system peformance; (3) survey of line outages of high voltage lines. This last subject has been made a joint study with a subcommittee of the transmission and distribution committee of the Edison Electric Institute.

The stations subcommittee has been studying: (1) flexibility for removal of parts in packaged substation units for industrial plants; (2) single versus 3-pole switching for 4-kv distribution system; (3) request for papers on increasing the capacity of existing distribution systems; (4) economics of the unit type of substation; (5) supervisory control versus automatic stations.

The subcommittee on lightning and insulators has been studying: (1) methods of predetermining lightning performance of transmission lines; (2) "Lightning Reference Book, Volume II;" (3) lightning characteristics of porcelain, wood, and air in series.

The subcommittee on insulated wires and cables has been devoting its time to an investigation of the thermal properties of buried cable systems—in duct and directly buried. It appears that a closer appreciation of the effective thermal resistivity of the soil surrounding both ducts and directly buried cables can be obtained. The subcommittee is seeking papers dealing with cable operation and design for presentation at national meetings.

The subcommittee on towers, poles and conductors has under consideration the following topics: (1) dancing conductors; (2) wood versus steel towers—economics; (3) conductor joints and splices; (4) cathodic protection of tower footings; (5) stainless steel static wires; (6) acetylene-flame cleaning for tower painting or repainting.

The subcommittee on distribution has had under consideration several subjects of an economic nature. However, it was found that these same subjects were being covered by Edison Electric Institute, and, therefore, they were dropped for further consideration by the subcommittee. This subcommittee sponsored jointly with the relay subcommittee of the committee on protective devices a conference during the past winter meeting on protection and design of distribution circuits to improve performance. Considerable interest was shown at the meeting, and there was not sufficient time to complete the discussion. Therefore, the committee is making plans to continue this joint interest with the committee on protective devices. It is hoped that they will be able to have another joint conference at the summer general meeting.

It is intended to have a meeting of the committee during the summer general meeting, at which two sessions are being sponsored.

COMMITTEE ON PROTECTIVE DEVICES

The committee continued to function as an executive group only. All the details of standardization and sponsoring of papers has been handled by the subcommittees. This arrangement has continued to function entirely satisfactorily.

Seven papers were sponsored by the committee at the winter meeting, and three are scheduled for presentation at the coming summer general meeting. In addition, the committee sponsored one conference session and was cosponsor of another at the winter meeting.

There have been three meetings of the main committee and another is scheduled for the near future.

Any projects which have been instituted, as well as the details of the accomplishments of the various subcommittees, are contained in the following reports submitted by the chairmen of the various subcommittees.

Switches, Fuses, and Insulators Subcommittee. This subcommittee held one meeting during the year. At present, a revision of standard 22 on switches and insulators is being prepared, and a revised draft of the proposed standard on interrupter switches also is being prepared.

Relays Subcommittee. The activities of the subcommittee included sponsoring six technical papers, including joint papers, two of them being subcommittee reports, three conference papers, and two conference sessions. In addition to a large number of meetings of the 11 working groups, the subcommittee held three regular meetings. The principal work of the subcommittee is carried on through the activities of working groups having the following specific assignments.

The working group on the bibliography of protective relaying has prepared and distributed to the members of the subcommittee, the committee on protective devices, and to a mailing list of 100 relay engineers in the United States copies of the "Relay Bibliography for 1946." This contains a listing of all technical articles published in the United States and foreign press dealing with various phases of protective relaying. These activities are continued from year to year, and periodically the bibliography is published for general distribution in the form of a technical paper.

The investigation of grounding practices for instrument transformer secondary circuits has been completed. The results of this undertaking and recommended practices are summarized in a subcommittee report "Grounding of Instrument Transformer Secondary Circuits," which was presented at the winter meeting and published in the April 1947, *ELECTRICAL ENGINEERING*. This working group has been discharged.

The group on instrument transformer standards practically has completed its work in connection with the revision of the ASA "Transformer Standard *C57*." The relays subcommittee has approved the revision of the test code and operating guides for that Standard which apply to instrument transformers, and suggestions for the final Standard have been passed on to the ASA transformer and operating guides committee. It is expected that this working group will be discharged at the close of the administrative year.

Following a preliminary report presented in January 1946, and a conference session at the summer meeting, the working group on transformer protection developed further information on certain phases of the transformer protection problem, such as the co-ordination of thermal protective devices with short-circuit relay protection, and evolved recommended short-time characteristics of thermal devices. A conference paper by E. T. B. Gross on "Simplicity in Transformer Protection," presented at the January 1947 winter meeting, brought out additional information and discussion of pressure relay protection and fault detection by means of gas accumulator elements. The results of this review and correlation of transformer protection are summarized in a subcommittee report, "Relay Protection of Power Transformers," scheduled for presentation at the summer general meeting, which will complete the work of this group.

In previous years, the working group on generator protection developed information on current practices through questionnaires and a conference session. Further work is necessary before definite recommendations can be made concerning practices for the relay protection of generators.

The correlation of distribution circuit protection practices and construction methods, with emphasis on the influence of these on the reduction of sustained faults, is a joint project of the relays subcommittee and the distribution subcommittee of the committee on power transmission and distribution. This group has endeavored to develop an awareness of the necessity of keeping adequate records in order to evaluate the various methods of improving service to distribution loads. A conference session was held at the summer meeting, introduced by two conference papers, and provided worth-while exchanges of information.

A revision of "Standard for Power Relays," ASA *C37*, has been undertaken by a working group. Following discussion and correspondence on suitable test voltages, relay definitions, and so forth, a preliminary draft of a proposed revision has been prepared and is being circulated to the relay subcommittee for comments and suggestions.

In November 1946, a working group began to study the desirable insulation levels of relay and control circuits. The test voltage required by the present standard for power relays is considered to be too low to guard against abnormal voltages which might occur in current transformer secondary and d-c control circuits. Although most relays now are being tested at voltages in excess of the present standard requirements, cases have been reported of improper relay performance as a result of abnormal secondary and control voltages. A preliminary survey is under way to determine the extent of this problem.

A new working group was organized in the fall of 1946 to study sensitive ground protection of transmission and distribution circuits. The benefits of such protection, including limitation of fault damage, improved service reliability, and the positive disconnection of broken conductors resting on the ground long have been recognized. Several papers have been published describing methods and results used with delta-connected or ungrounded systems. These methods are being reviewed and information collected on schemes which have been tried or proposed for 4-wire multigrounded systems.

A study of transmission line protection has been undertaken by a working group. Emphasis has been placed in recent years on the need for relaying systems that will not limit the emergency load carrying ability of transmission lines with swings approaching system stability limits. General application methods, backup relaying, and special problems will receive attention. The group has evolved a "typical" transmission system to be used in certain studies.

A new working group to study electronic protective relay applications has been formed in response to suggestions from a number of sources. As a beginning, a list is being prepared of existing applications of electronic devices to protective relay systems. Following this, it is planned to explore those features of electronic devices which tend to give them a place in competition with other forms of equipment, and especially to anticipate where they might provide a facility not hitherto available.

Fault Limiting Devices Subcommittee. Work on AIEE Standard 32, "Neutral Grounding Devices," has been completed, and the final draft released to the Standards committee. It has received all required committee approvals as a new standard.

The preparation of the third report on "Present-Day Grounding Practices" is well advanced. It is expected to be presented at the summer general meeting.

Replies received from industry, in the survey of its grounding practices, cover 510 power systems, 101,000 miles of transmission and distribution circuits of 22 kv and above, and 33,750,000 kva of generating capacity. The report is to be factual, giving interpretations but not recommendations, and will be in four parts:

I. Introduction.
    A. Purpose and Scope.
    B. Summary of Results.

II. Grounding Practices at Generating Stations.
III. Grounding Practices on Transmission and Distribution Systems.
IV. Appendixes.
    A. Supplementary Tables for Part II.
    B. Supplementary Tables for Part III.

The bibliography on resonant neutral grounding is to cover the period from 1918 to date. It is to have future addenda at regular intervals to keep up with new publications. At present, the bibliography is finished to about 1935. By next fall it is expected to be completed through 1946.

A field survey of the continuous loads of resonant neutral grounding devices is getting under way. Better, and perhaps more economical, designs of ground fault neutralizers and associated grounding transformers can be made with more accurate data on the actual continuous load demands upon them.

A new project on high resistance neutral grounding of alternators has been started.

The subcommittee organization, as appended to the October 31, 1947, minutes of the committee on protective devices, remains unchanged, except that to the title of "Working Group on Revision of Standard 32" there should be added "and Field Survey of the Continuous Loads of Resonant Neutral Grounding Devices."

Circuit Breakers and Assembled Switchgear Subcommittee. The work of the subcommittee was handled mainly by five active working groups, each of which discharged its responsibility efficiently and quickly as could be done without sacrificing thoroughness.

The working group on low voltage air circuit breakers completed the work on the "Low-Voltage Air Circuit Breaker," Standard 20, obtained the necessary approvals of the subcommittee and the committee on protective devices, and referred the Standard to the Standards committee which published it. The working group is studying the following subjects: (1) cascading; (2) short time rating; and (3) selective tripping. The group has circulated a questionnaire to obtain information on how successful has been the experience in operating circuit breakers in cascade. It also has promoted preparation of technical program papers, and a complete session on small air circuit breakers is planned for the summer meeting.

The working group on switchgear assemblies reports that the "Assembled Switchgear," Standard 27, is in good shape, but does not include impulse test levels. It was decided to revise the Standard primarily for this purpose, but at the same time review the entire Standard.

The working group on power circuit breakers completed the study of the method of defining the interrupting rating of power circuit breakers and reaffirmed its recommendation that the basic rating be based on the current interrupted at the instant of parting the contacts.

The group recommended against adopting a proposed method of rating using the current during the first half cycle, because it would create confusion among those responsible for the application of circuit breakers, would present difficulties in rerating those circuit breakers, require revision of standards, and make it necessary to revise all existing application data.

In co-operation with the working group on switchgear assemblies, the matter of determination of test voltages for secondary circuits was studied. It was determined that test voltages for secondary circuits are specified adequately in AIEE Standard 27. Also in co-operation with the working group on switchgear assemblies, the group considered the request to prepare a standard covering the fusing of control circuits.

The working group on calculating short-circuit current for low voltage circuits again was unable to complete the assignment to revise the method of calculating short-circuit currents for low voltage circuits. There is a need for further test information before this work can be completed. Owing to industrial conditions during the past year, in which all facilities for making such tests were loaded beyond capacity, the committee was unable to get the data with which to complete its work.

The subcommittee endorsed the proposed plan for reorganizing the Institute's technical committees, but requested that it be given the opportunity to review and study further the selection and scope of the proposed committees before the final organization is determined.

Lightning Protective Devices Subcommittee. A working group has obtained impulse breakdown characteristics from the manufacturers of distribution expulsion-type arresters, which has been compiled into a report. The report is being circulated in the working group for approval, after which it will be sent to the subcommittee for final approval.

The working group on rotating a-c machines collected data from 54 power companies, and prepared a report which was submitted to the lightning protective devices subcommittee at the winter meeting for comments and suggestions. The subcommittee requested a review of the replies to see if sufficient information was available to show the policy followed by the different companies. The subcommittee voted to present the results of this survey to the Institute as a committee report at the winter general meeting in 1948.

A meeting of the working group on unit substations was held in January, at which decisions were made to collect data by a limited survey which will cite specific cases where equipment failure of flashovers have occurred, and to investigate and clarify certain technical points which are vital to this problem.

The working group designated to combine and revise AIEE Standards 28, 24, and 47 circulated a fourth draft of this standard to the working group and members of the lightning protective devices subcommittee for comments and suggestions. The subcommittee voted to exclude the material covering application from the standard and to establish a new project, which will have as its objective a report covering an application guide for the selection of arrester voltage ratings based upon system operating conditions.

The lightning protective devices subcommittee recommends that, when the new appointments are made in August 1947, a project be set up to prepare an application guide to aid in the selection of methods for lightning protection of substations.

COMMITTEE ON APPLICATION OF ELECTRICITY TO THERAPEUTICS

The committee held one meeting during the year. At this meeting, which was well attended, there was an extended discussion as to the scope of the committee's activities and its objectives. The members concurred in the definition of the committee's scope as outlined by the board of directors. The field of the committee's activity is broad and, in some cases, co-operation and joint action with other committees would be appropriate.

The committee is very much interested in promoting standards that should be observed in the design features of therapeutic apparatus. This standards work should be carried on in collaboration with the committee on safety.

The committee also is interested deeply in the effects on humans of heat lamps, sun lamps, diathermy, X-ray equipment, and the like, and in the development of new electrical means for diagnosis and treatment of disease. In this connection, the committee thinks it should maintain contact with the council on physiotherapy of the American Medical Association, and therefore, is asking the board of directors for permission to appoint a liaison representative to maintain contact with the medical profession.

The committee is laying plans for a symposium on the uses of electricity in therapeutics.

Awards

CHARLES LE GEYT FORTESCUE FELLOWSHIP

This fellowship was established as a memorial to Charles Le Geyt Fortescue in recognition of his valuable contributions to the electric power industry, and provides a minimum allowance of $500 a year for graduate study in electrical engineering.

Two awards were made for the academic year 1947–48: Paul Kaczmarczik, for graduate study at the University of Pennsylvania; and Theordore G. Mihran for graduate study at Stanford University.

COMMITTEE ON MEMBERS-FOR-LIFE FUND

No awards were made last year in connection with the summer meeting as was anticipated in the committee report of a year ago, because no Branch paper prizes were awarded, because of conditions instant to the aftermath of the war.

Special attention of the counselor in each of the Student Branches of the odd-numbered Districts was called to these awards, expense-paid trip to the summer general meeting for the winners of the Branch paper prizes, last October. It is too early to know whether any awards will be made for the 1947 summer general meeting.

EDISON MEDAL

The Edison Medal, awarded by a committee composed of 24 members of the Institute, was presented for 1946 to Doctor Lee de Forest, president of the Lee de Forest Laboratories, Inc., Los Angeles, Calif., "for pioneering achievements in radio and for the invention of a grid-controlled vacuum tube with its profound technical and social consequences." The presentation took place January 27, 1947, during the winter meeting. The medal may be awarded annually for "meritorious achievement in electrical science, electrical engineering, or the electrical arts."

LAMME MEDAL

The Lamme Medal committee awarded the medal for 1946 to John B. MacNeill, manager of the switchgear and control division of the Westinghouse Electric Corporation, East Pittsburgh, Pa., "for his foresight, leadership, and creative contribution in the development of switching equipment." Arrangements are being made for the presentation of the medal at the annual business meeting in Montreal, Quebec, Canada, June 11, 1947. The medal may be awarded annually to a member of the AIEE "who has shown meritorious achievement in the development of electric apparatus or machinery."

HOOVER MEDAL

The Hoover Medal was established through a trust fund created by a gift from Conrad N. Lauer and is to be awarded periodically "to a fellow engineer for distinguished public service" by a board representing the ASCE, American Institute of Mining and Metallurgical Engineers, ASME, and AIEE. The eighth medal, for 1946, was awarded to Doctor Vannevar Bush, president of the Carnegie Institution of Washington, and was presented to him on January 30, 1947, during the AIEE winter meeting.

JOHN FRITZ MEDAL

The John Fritz Medal board of award is composed of representatives of the ASCE, AIME, ASME, and AIEE. The medal may be awarded annually for notable scientific or industrial achievements. The 1947 medal was awarded to Doctor Lewis Warrington Chubb, director of research, Westinghouse Electric Corporation, East Pittsburgh, Pa., for "pioneering genius and notable achievements during a long career devoted to the scientific advancement of the production and utilization of electric energy." The medal was presented on January 29, 1947, during the AIEE winter meeting.

WASHINGTON AWARD

The Washington Award for 1947 was bestowed upon Doctor Karl T. Compton, president of the Massachusetts Institute of Technology, Cambridge, Mass., "for his scientific and engineering activities, which have contributed considerably to the happiness, comfort, and well-being of humanity." The presentation was made at a dinner in Chicago, Ill., in February. The award may be made annually to an engineer by the commission of award composed of nine representatives of the Western Society of Engineers and two each of the ASCE, AIME, ASME, and AIEE.

ALFRED NOBLE PRIZE

This prize, established in 1929, consists of a certificate and a cash award from the income of a fund contributed by engineers and others to perpetuate the name and achievements of Alfred Noble, past president of the ASCE, and of the Western Society of Engineers. It may be made to a member of any of the co-operating societies, ASCE, AIME, ASME, AIEE, or WSE, for a technical paper of particular merit accepted by the publication committee of any of these societies, provided the author, at the time of such acceptance, is not over 30 years of age.

INSTITUTE PRIZES

The committee has reviewed further the proposed revised practice covering the award of Institute prizes, with particular reference to comments received from the chairman of the Sections committee. This review has resulted in some changes in the proposed prize award practice, and a new proposal has been submitted to the board of directors.

Joint Activities

UNITED ENGINEERING TRUSTEES, INC.

This organization manages property and funds held jointly by the four Founder Societies, including the Engineering Societies Building, the Engineering Societies Library, and the endowment funds of the Engineering Foundation.

The building is occupied fully by engineering organizations, and additional space is needed both for offices and for meetings. Two of the Founder Societies have been forced to rent space in other buildings.

A committee of the UET is endeavoring to develop tentative plans for the remodeling of the building or the procurement of a new building to meet the needs of the founder societies and, if possible, bring in other engineering societies.

An abstract of the annual report for the year ended September 30, 1946, appeared in *ELECTRICAL ENGINEERING*, February 1947, page 201.

Table XII. Employment Service—1946

Month	Men Registered: New York	Chicago	San Francisco	Detroit	Total	Men Placed: New York	Chicago	San Francisco	Detroit	Total
January	338	106	134	49	627	42	27	25	13	107
February	251	86	126	60	523	28	18	19	9	74
March	296	79	182	81	638	34	18	20	13	85
April	246	98	113	65	522	43	20	24	20	107
May	226	73	138	79	516	38	25	31	16	110
June	210	86	121	40	457	45	14	33	15	107
July	247	58	81	62	448	50	16	20	18	104
August	201	79	128	57	465	35	18	27	25	105
September	207	61	112	64	444	38	11	29	20	98
October	214	60	113	56	443	47	10	34	17	108
November	194	58	92	55	399	38	15	14	12	79
December	164	60	70	45	339	32	18	12	11	77
Total	2,794	904	1,410	713	5,821	470	210	288	189	1,153

ENGINEERING FOUNDATION

The Engineering Foundation was established in 1914 as a joint organization of the four societies, ASCE, AIME, ASME, and AIEE, for "the furtherance of research in science and engineering, and the advancement in any other manner of the profession of engineering and the good of mankind."

The foundation has been supporting 14 research projects, and new projects are constantly under consideration. Each research project supported by it is under the sponsorship of one of the founder societies.

The sponsorship of the Welding Research Council has been broadened to include all the four Founder Societies as well as the American Welding Society. The council operates through ten principal committees.

An abstract of the annual report for the year ended September 30, 1946, appeared in *ELECTRICAL ENGINEERING*, February 1947, pages 199–200.

ENGINEERING SOCIETIES LIBRARY

The Engineering Societies Library was formed by combining the separate libraries of the ASCE, AIME, ASME, AIEE, and preparing a composite card catalogue.

Special services rendered by the library include: photoprints, searches, abstracts, translations, bibliographies, book loans by mail. All services have had greater use except the photostat which decreased about nine per cent below the extensive demands during the war.

Wartime conditions prevented the usual growth in the book and magazine collections. These deficiencies are being overcome rapidly.

An abstract of the annual report for the year ended September 30, 1946, appeared in *ELECTRICAL ENGINEERING*, February 1947, pages 200–01.

EMPLOYMENT SERVICE

Operating as an incorporated nonprofit organization, the Engineering Societies Personnel Service, Inc., assists members of the Founder Societies desiring to secure new positions and employers searching for engineers. Nonmembers may receive such assistance when positions available cannot be filled by members.

Offices are operated in New York; Detroit, Mich.; Chicago; and San Francisco, Calif.; with the co-operation of the Engineering Society of Detroit in that city, the Western Society of Engineers in Chicago, and the Engineers Club of San Francisco in that city.

For several years, the service has been on a self-supporting basis. A record of registration and placements during the past year is given in Table XII.

ENGINEERS' COUNCIL FOR PROFESSIONAL DEVELOPMENT

Organized in 1932 to engage in activities leading toward the enhancement of the professional status of the engineer, this council now includes three representatives of each of the eight participating organizations: the ASCE, AIEE, ASME, AIME, SPEE, American Institute of Chemical Engineers, National Council of State Boards of Engineering Examiners, and the Engineering Institute of Canada.

During the past year, as in previous wartime years, inspections of engineering curricula by the committee on engineering schools were held to a minimum. Reexamination of all engineering curriculums previously accredited has been recommended by the committee on engineering schools. The accrediting of technical institutes is well under way. Seven curricula were accredited in October 1946.

Other activities are carried on by committees whose titles indicate the nature of their work: student selection and guidance, professional training, professional recognition, information, engineering ethics, employment conditions for engineers, and ways and means.

A comprehensive report on the activities during the year ended September 30, 1946, was published in *ELECTRICAL ENGINEERING*, January 1947, pages 102–05.

ENGINEERS JOINT COUNCIL

This council, formerly known as the joint conference committee, is composed of the presidents, immediate past presidents, and secretaries of the Founder Societies and the AIChE. Its functions are to consider matters of interest to the societies and to make recommendations to their governing bodies.

Reports on the industrial disarmament of Germany and Japan were prepared for the State and War Departments.

A panel was organized to advise committees of Congress regarding desirable amendments to the National Labor Relations Act to prevent grouping together of professional and nonprofessional employees.

The committee on the economic status of the engineer has completed and EJC has published the first part of a manual on collective bargaining, and a report on a preliminary survey of employer practice regarding engineering graduates.

The committee on organization of the engineering profession is making comprehensive studies of engineering organizations of local, state, and national types.

REPRESENTATIVES

A complete list of about 40 joint bodies upon which the Institute is represented appears in the Year Book and in the October issue of *ELECTRICAL ENGINEERING* each year.

Appreciation

To the AIEE committees, to District, Section, and Branch officers, and to the members in general, the board of directors expresses deep appreciation of the extensive expansions in activities and the continuing rapid increase in membership, and extends thanks for the splendid co-operation received.

Respectfully submitted for the board of directors.

H. H. HENLINE
Secretary

Members of the AIEE board of directors present at the North Eastern District meeting were left to right: (seated) T. G. LeClair, M. J. McHenry, W. E. Wickenden, J. E. Housley, C. A. Powel, and W. I. Slichter; (standing) E. P. Yerkes, P. L. Alger, C. M. Laffoon, F. L. Lawton, S. H. Mortensen, H. H. Henline, J. F. Fairman, R. T. Henry, J. R. North, D. A. Quarles, W. C. Smith, E. W. Davis, H. B. Wolf, and L. M. Robertson

HASKINS & SELLS
CERTIFIED PUBLIC ACCOUNTANTS

1 EAST 44TH STREET
NEW YORK 17

May 19, 1947

American Institute of Electrical Engineers,
33 West 39th Street, New York.

Dear Sirs:

We have examined the balance sheet of the American Institute of Electrical Engineers, and schedule of securities owned, as of April 30, 1947, and the related statements of cash receipts and disbursements of operating and restricted funds for the year ended that date, have reviewed the accounting procedures of the Institute, and have examined its accounting records and other evidence in support of such financial statements. Our examination was made in accordance with generally accepted auditing standards applicable in the circumstances and included all auditing procedures we considered necessary, which procedures were applied by tests to the extent we deemed appropriate in view of the system of internal control.

In our opinion, the accompanying balance sheet, schedule of securities owned, and statements of cash receipts and disbursements fairly present, respectively, the financial condition of, and securities owned by, the Institute as of April 30, 1947, and its recorded cash receipts and cash disbursements for the year ended that date, in conformity with generally accepted accounting principles and practices applied on a basis consistent with that of the preceding year.

Yours truly,

(*Signed*) HASKINS & SELLS

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Balance Sheet, April 30, 1947

Exhibit A

ASSETS		
Property Fund Assets:		
One-fourth interest in physical properties of United Engineering Trustees, Inc.:		
Land, buildings, and equipment (less depreciation and renewal reserve)	$352,018.07	
Funded depreciation and renewal reserve	146,430.41	
Total	$498,448.48	
Equipment:		
Library (volumes and fixtures)—estimated value	36,366.37	
Office furniture and fixtures (less reserve for depreciation, $28,875.98)	12,361.48	
Works of art, etc.	3,001.35	
Cash (no change during year)	612.91	
Total property fund assets		$ 550,790.59
Restricted Fund Assets:		
Securities—at cost, less reserve, $1,788.15 (quoted market value, $629,189.88)—Schedule 1	$609,819.96	
Cash (Exhibit *C*)	23,488.62	
Accrued interest receivable	125.40	
Total restricted fund assets		633,433.98
Operating Fund Assets:		
Cash (not including $1,664.75 for Federal taxes withheld from employees)—(Exhibit *B*)	$ 6,883.37	
Accounts receivable:		
Members—for dues (less reserve, $4,000.00)	9,597.71	
Advertisers	2,004.52	
Miscellaneous	3,098.89	
Accrued interest receivable	6,673.27	
Inventories:		
TRANSACTIONS, etc.	1,275.00	
"Electrical Definitions"	2,449.20	
Work in process (May issue of *ELECTRICAL ENGINEERING*, etc.)	8,207.86	
Text and cover paper	14,164.08	
Badges	5,476.43	
Total operating fund assets		59,830.33
Total		$1,244,054.90

LIABILITIES		
Property Fund Reserve		$ 550,790.59
Restricted Fund Reserves:		
Reserve capital fund	$605,931.88	
Life membership fund	8,733.46	
Member-for-Life fund	6,908.41	
International Electrical Congress of St. Louis library fund	6,264.83	
Lamme Medal fund	4,440.44	
Mailloux fund	1,154.96	
Total restricted fund reserves		633,433.98
Operating Fund Reserves, Liabilities, etc.:		
Accounts payable	$ 25,595.93	
Deferred income:		
Dues received in advance	3,699.09	
Entrance fees and dues advanced by applicants for membership	2,145.60	
Subscriptions to publications received in advance	17,777.86	
Miscellaneous (including unallocated receipts)	1,367.33	
Operating fund reserves	9,244.52	
Total operating fund reserves, liabilities, etc.		59,830.33
Total		$1,244,054.90

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Statement of Cash Receipts and Disbursements of Operating Fund for the Year Ended April 30, 1947

Exhibit B

Cash on Deposit with The National City Bank of New York, May 1, 1946 (not including $1,302.87 for Federal taxes withheld from employees)			$ 81,379.47
Receipts:			
Dues (including $143,232.00 allocated to *ELECTRICAL ENGINEERING* subscriptions)		$305,014.02	
Advertising		106,499.51	
TRANSACTIONS subscriptions		9,770.77	
ELECTRICAL ENGINEERING subscriptions		27,811.67	
Miscellaneous publications (preprints, Standards, special reports, etc.)		32,529.24	
Students' fees		24,217.70	
Entrance fees		19,901.62	
Membership badges		4,443.03	
Transfer fees		3,140.38	
Interest and dividends on investments of Restricted Capital Fund		18,804.53	
Miscellaneous		306.23	
Total receipts			552,438.70
Total			$633,818.17
Disbursements:			
Publications expense:			
ELECTRICAL ENGINEERING text	$132,721.26		
ELECTRICAL ENGINEERING advertising	45,163.74	$177,885.00	
TRANSACTIONS		10,571.30	
PROCEEDINGS		2,633.69	
"Year Book"		7,488.69	
Miscellaneous publications (preprints, Standards, etc.)		26,043.51	
Institute meetings		19,020.94	
Institute Sections		60,532.69	
Institute Branches		4,695.60	
Finance committee		769.99	
Headquarters committee		263.50	
Membership committee		13,295.39	
Standards committee		13,100.27	
Technical committees		5,829.82	
Committee on Institute publicity		1,365.53	
Planning and co-ordination committee		9,281.06	
Edison Medal committee		244.01	
Committee on collective bargaining and related matters		3,458.91	
Forward		$356,479.90	$633,818.17
Total (forward)			$633,818.17

Total (forward)		$633,818.17
Disbursements (forward)	$356,479.90	
Traveling expenses:		
Geographical Districts:		
Executive committees	9,294.64	
Vice-presidents	1,489.03	
Conferences on Student activities	7,017.45	
Board of directors	9,435.18	
Nominating committee	1,696.85	
President's appropriation	3,153.72	
AIEE representatives	363.70	
Administrative expenses	71,158.12	
Geographical Districts—Branch paper prizes	235.88	
Institute prizes—national	412.24	
Retirement system AIEE—normal contribution	5,816.89	
American Co-ordinating Committee on Corrosion	50.00	
American Standards Association	1,500.00	
Canadian Radio Technical Planning Board	10.00	
Engineers' Council for Professional Development	2,687.50	
Engineering Foundation Project—Welding research	250.00	
Engineers Joint Council:		
Economic Status of the Engineer	6,033.43	
General expenses	981.15	
Hoover Medal	57.69	
John Fritz Medal	220.93	
National Committee State Board Engineering Examiners	500.00	
National Fire Protection Association—Dues	60.00	
Radio Technical Planning Board	400.00	
United Engineering Trustees, Inc.		
Building assessment	17,813.56	
Library assessment	11,845.00	
International Commission on Illumination	450.00	
Representation on labor panel and incidental expenses	2,275.54	
Lamme Medal expense (see Exhibit *C*)	107.15	
Membership badges	8,096.38	
Legal services	250.00	
Office furniture and fixtures and repairs	4,016.00	
Headquarters repairs, etc.	1,232.66	
Rent, etc., 500 Fifth Avenue	3,655.30	
Total	$529,045.89	
Transfers:		
To reserve capital fund	96,011.59	
To Member-for-Life fund	1,877.32	
Total disbursements		$626,934.8
Cash on Deposit With The National City Bank of New York, April 30, 1947 (not including $1,664.75 for Federal taxes withheld from employees)		$ 6,883.37

AMERICAN INSTITUTE OF ELECTRICAL ENGINEERS

Exhibit C. Statement of Cash Receipts and Disbursements of Restricted Funds for the Year Ended April 30, 1947

		Restricted Funds					
	Total	Reserve Capital Fund	Member-for-Life Fund	Life Membership Fund	International Electrical Congress of St. Louis Library Fund	Lamme Medal Fund	Mailloux Fund
Cash on Deposit With The National City Bank of New York and Various Savings Banks, May 1, 1946	$ 47,304.66	$ 36,676.03	$5,031.09	$3,637.91	$ 661.80	$160.00	$1,137.83
Receipts:							
Proceeds from sales, etc. of securities	$ 32,223.13	$ 21,612.16		$5,153.12	$5,457.85		
Income from bonds	377.34			122.95	94.39	$160.00	
Interest on bank balances	70.28			53.15			$ 17.13
Transfers from operating fund	97,888.91	96,011.59	1,877.32				
Life membership fees	327.90			327.90			
Liquidating dividend—International Match Realization Company, Ltd.	63.00	63.00					
Total receipts	$130,950.56	$117,686.75	$1,877.32	$5,657.12	$5,552.24	$160.00	$ 17.13
Total	$178,255.22	$154,362.78	$6,908.41	$9,295.03	$6,214.04	$320.00	$1,154.96
Disbursements:							
Purchase of securities	$153,997.08	$143,386.11		$5,153.12	$5,457.85		
Transfer to operating fund	609.52			609.52			
Purchase of medal, cost of engraving, etc. (exclusive of $107.15 paid from general fund)	160.00					$160.00	
Total disbursements	$154,766.60	$143,386.11		$5,762.64	$5,457.85	$160.00	
Balance on Deposit With The National City Bank of New York and Various Savings Banks, April 30, 1947	$ 23,488.62	$ 10,976.67	$6,908.41	$3,532.39	$ 756.19	$160.00	$1,154.96

Securities Owned, April 30, 1947

Schedule 1

	Principal Amount of Bonds or Number of Shares of Stock	Restricted Funds				
		Reserve Capital Fund	Life Membership Fund	International Electrical Congress Library Fund	Lamme Medal Fund	Total
Railroad Bonds:						
Atlantic Coast Line First Consolidated 4%, due 1952	$ 4,000.00				$4,253.78	$ 4,253.78
Baltimore & Ohio, Pittsburgh, Lake Erie & West Virginia System 4%, due 1980	10,000.00	$ 6,450.00				6,450.00
Chicago & Erie Railroad Company 5% first mortgage, due 1982, Registered	1,000.00	1,105.00				1,105.00
New York Central Railroad Company 4% series *A* consolidated mortgage, due 1998	15,000.00	9,812.50				9,812.50
Northern Pacific Railway Company 4½% collateral trust, due 1975	15,000.00	15,307.50				15,307.50
St. Louis–San Francisco Railway Company 4 % series *A*, first mortgage, due 1997	(*a*) 1,200.00	1,200.00				1,200.00
St. Louis–San Francisco Railway Company 4% series *A*, first mortgage, scrip	(*a*) 198.00	198.00				198.00
St. Louis–San Francisco Railway Company 4½% series *A*, second mortgage, income bonds, due 2022	(*a*) 1,300.00	1,300.00				1,300.00
St. Louis–San Francisco Railway Company 4½% series *A*, second mortgage, income bonds, scrip	(*a*) 61.10	61.10				61.10
Total railroad bonds		$ 35,434.10			$4,253.78	$ 39,687.88
Public Utility Bonds:						
American Telephone & Telegraph Company 2¾% convertible debentures, due 1961	$25,000.00	$ 17,163.50	$5,153.12	$5,457.85		$ 27,774.47
New York & Queens Electric Light & Power Company 3½% first and consolidated mortgage, due 1965	10,000.00	10,400.00				10,400.00
Total public utility bonds		$ 27,563.50	$5,153.12	$5,457.85		$ 38,174.47
United States Government Bonds:						
Treasury Savings bonds series *D*, due July 1, 1949	$10,000.00	$ 7,644.00				$ 7,644.00
Treasury Savings bonds series *D*, due January 1, 1950	10,000.00	7,500.00				7,500.00
Treasury bonds 2%, due 1950/48	77,000.00	78,130.94				78,130.94
Treasury bonds 2%, due 1950/48, Registered	3,000.00	3,060.94				3,060.94
Treasury bonds 2%, due March 15, 1952/50	25,000.00	25,617.19				25,617.19
Defense bonds series *F*, due June 1, 1953	34,000.00	25,160.00				25,160.00
Defense bonds series *G*, 2½%, due December 1, 1954	18,000.00	18,000.00				18,000.00
Treasury Savings bonds series *G*, 2½%, due September 1, 1955	40,000.00	40,000.00				40,000.00
Treasury Savings bonds series *G*, 2½%, due November 1, 1956	17,000.00	17,000.00				17,000.00
Treasury Savings bonds series *G*, 2½%, due May 1, 1957	20,000.00	20,000.00				20,000.00
Treasury Savings bonds series *G*, 2½%, due October 1, 1957	30,000.00	30,000.00				30,000.00
Total United States Government bonds		$272,113.07				$272,113.07
Capital Stock:						
American Can Company	60 shares	$ 4,988.40				$ 4,988.40
American Telephone and Telegraph Company	100 shares	17,454.15				17,454.15
Atchison, Topeka & Santa Fe Railway Company preferred	200 shares	19,174.71				19,174.71
Boston Edison Company	200 shares	4,927.50				4,927.50
Commonwealth Edison Company	200 shares	7,580.68				7,580.68
Consolidated Natural Gas Company	11 shares	221.92				221.92
Dow Chemical Company $4.00 cumulative preferred series *A*	100 shares	11,547.50				11,547.50
Eastman Kodak Company	60 shares	10,694.11				10,694.11
E. I. du Pont de Nemours & Company	80 shares	13,096.68				13,096.68
General Electric Company	200 shares	7,748.66				7,748.66
General Motors Corporation $5.00 preferred	200 shares	25,820.00				25,820.00
General Motors Corporation	100 shares	4,235.53				4,235.53
Insurance Company of North America	100 shares	10,847.50				10,847.50
International Harvester Company	100 shares	5,030.50				5,030.50
International Match Realization Company, Ltd., voting trust certificates for capital shares of International Match Corporation	6 shares*	1,788.15*				1,788.15*
Louisville & Nashville Railroad Company	100 shares	6,278.13				6,278.13
Ohio Edison Company 4.40% preferred	200 shares	21,279.25				21,279.25
Pacific Gas and Electric Company	200 shares	8,784.35				8,784.35
Public Service Corporation of New Jersey 6% preferred	100 shares	11,150.00				11,150.00
St. Louis–San Francisco Railway Company voting trust certificates for 5% series *A* preferred stock	(*a*) 21 1800/10000ths shares	582.75				582.75
St. Louis–San Francisco Railway Company voting trust certificates for common stock	(*a*) 42 6000/10000ths shares	357.00				357.00
Scoville Manufacturing Company 3.65% cumulative preferred	100 shares	10,111.25				10,111.25
Sears, Roebuck and Company	400 shares	6,014.97				6,014.97
Standard Oil Company of Indiana	200 shares	8,170.32				8,170.32
Standard Oil Company of New Jersey	200 shares	9,601.26				9,601.26
Union Carbide & Carbon Corporation	100 shares	7,277.42				7,277.42
United Fruit Company	(*b*) 300 shares	11,985.00				11,985.00
United States Steel Corporation 7% cumulative preferred	100 shares	14,885.00				14,885.00
Total capital stocks		$261,632.69				$261,632.69
Total		$596,743.36	$5,153.12	$5,457.85	$4,253.78	$611,608.11
* Less reserve in full for securities considered to be of doubtful value		1,788.15				1,788.15
Total Securities, Less Reserve		$594,955.21	$5,153.12	$5,457.85	$4,253.78	$609,819.96

(*a*) In connection with the reorganization of the St. Louis–San Francisco Railway Company the securities marked (*a*) were received during the year in exchange for St. Louis–San Francisco Railway Company 5% prior lien mortgage series *B*, due 1950 (certificates of deposit), registered, stamped, which were surrendered.

(*b*) Stock was split in June 1946 by issuance of two additional shares for each one held.

OF CURRENT INTEREST

Electrical and Photometric Units Changed

In pursuance of decisions of the International Committee on Weights and Measures, the National Bureau of Standards will introduce as of January 1, 1948, revised values of the units of electricity and of light. While the definitions of the units and the methods of fixing their magnitudes will be quite different from those of the present practical systems, the changes in magnitude will be so small as to affect appreciably only measurements of high precision. In certificates for standards and instruments issued by the Bureau during 1947 values will be given in both the old and the new units.

The electrical units of the "international" system will be superseded by those of the "absolute" system derived from the fundamental mechanical units of length, mass, and time by use of accepted principles of electromagnetism, with the value of the permeability of space taken as unity in the centimeter-gram-second system or as 10^{-7} in the corresponding meter-kilogram-second system. Actually all of the common electrical units fall into the mks system. This revision constitutes a return to the basic principle, always recognized as desirable, of having the electrical units consistent with the fundamental mechanical units.

The international ohm and volt now in use are slightly larger than the corresponding absolute units; consequently numerical values of resistance and voltage are slightly larger when expressed in absolute units than when expressed in international units. In the United States the factors recommended for conversion to the absolute basis are 1.000495 for resistances and 1.00033 for voltages. For power or energy therefore the factor is 1.000165, but for most purposes the round value 1.0002 is amply precise.

The new system of photometric units takes as the primary standard a black-body radiator operated at the temperature of freezing platinum. The "candle," unit of intensity, is defined as 1/60 of the intensity of one square centimeter of such a radiator. Other units are derived from the candle, with the provision that when differences of color are involved the evaluation shall be made by means of standard spectral luminosity factors which have been adopted by the International Commission on Illumination and the International Committee on Weights and Measures. For the types of lamps now in common use the ratings under this new system will be practically the same as those now in effect.

The adjustment of values of the units now proposed will consummate a movement initiated by committees of the American Institute of Electrical Engineers in 1927. The formal action of the Institute was a resolution adopted by the board of directors June 27, 1928, reading in part as follows:

> . . . Whereas the legalization of the absolute ohm and ampere and the units derived from them (these units to be realized by the national standardizing laboratories) would avert the recurring proposals for revision of the values of the legalized units, and would establish the electrical units on a permanent legal basis: Therefore be it
>
> Resolved, That the American Institute of Electrical Engineers hereby urges the Bureau of Standards and foreign national standardizing laboratories to undertake as soon as possible the additional researches necessary in order that the absolute ohm and absolute ampere based on the centimeter-gram-second electromagnetic system, with the absolute volt, watt, and other units derived from them, may be legalized in place of the international ohm and ampere and their derived units . . .

In order to obtain a consensus of American organizations the National Bureau of Standards had formed an Advisory Committee consisting of representatives named by the National Academy of Sciences, the American Institute of Electrical Engineers, the American Physical Society, the National Electric Light Association, the Association of Edison Illuminating Companies, the National Electrical Manufacturers' Association, and the American Telephone and Telegraph Company. On June 16, 1928, this committee unanimously adopted the following resolution:

> Resolved, that in the opinion of this committee, in view of improvements which are being made in absolute measurements, electrical standards should in future be based upon the absolute system of units."

These proposals were presented by the National Bureau of Standards to an Advisory Committee on Electricity established in 1927 by the International Committee and the Seventh General Conference on Weights and Measures. The proposals were accepted in substance, and in 1929 the International Committee adopted a resolution translated as follows:

> In view of the great importance of unifying the system of electrical measurement upon a basis free from arbitrary characteristics, the absolute system, derived from the centimeter-gram-second system, should replace the international system of units for all measurements in science and industry.

The Eighth General Conference in 1933 approved the principle of substituting the absolute system of electrical units for the international system, and delegated to the International Committee the power to fix the ratios between the corresponding units of the two systems and to set the date for adoption of the new units without waiting for another conference. It was then expected that standards of the absolute system could be established, at least provisionally, in 1935.

In 1935 the International Committee felt compelled to allow more time, but set the end of 1938 for the completion of absolute measurements; February 1939, for establishment of values for standards by the Advisory Committee on Electricity; and January 1, 1940, for the introduction of the new values in practice. At meetings of the International Committee in 1937 and of the Advisory Committee on Electricity in 1939 reports from the national laboratories were reviewed and detailed arrangements were made for introducing the new units. The outbreak of war in September 1939, prevented the execution of these plans. In October 1946, the International Committee met again and chose January 1, 1948, as the date for putting the new units into use.

Personnel Change in FCC. Commodore E. M. Webster, retired chief of communications of the United States Coast Guard, has been named by President Truman to fill the vacancy on the Federal Communications Commission, and the appointment has been confirmed by the Senate. This brings the Commission up to its full strength of seven members for the first time since the resignation of P. A. Porter. The commission also announced that it was accepting with regret the resignation of Chief Engineer G. P. Adair, who plans to open offices as a radio engineering consultant. His position will be filled by G. E. Sterling, assistant chief engineer.

Technical Societies Council of New York Organized

The Technical Societies Council of New York has announced its incorporation under the laws of the State of New York. The council is composed of engineering and technical societies in greater New York and has as its main objective the advancement of engineering, scientific, or technical knowledge and the practice of high professional standards. The American Institute of Electrical Engineers is one of the 13 charter member societies of the council. Each member society elects two delegates to represent it on the council. W. J. Barrett (M '36), and C. S. Purnell (M '35) who is also on the board of directors of the council, are the AIEE delegates.

The purposes of the council are:

> To provide a medium for consultation and advice by the member societies on matters of mutual interest.
>
> To encourage interest in participation in public affairs which are scientific or technical in scope.
>
> To cultivate greater appreciation by the public of the part which engineering, science, and technology contribute to human welfare.
>
> To provide a means of more effective public service by the member societies.
>
> To encourage greater unification of the interests of the engineering, scientific, and technical societies and co-

operate in a general program for the enhancement of the status of their members.

To promote co-ordination and integration of the inter-organization activities of the member societies.

To publish information of interest to the member societies.

To co-operate with organizations having similar objectives in other communities.

It is expected that other engineering, scientific and technical societies whose qualifications conform with the requirements of the council's constitution will become members.

Radar Bands Allocated. The Federal Communications Commission has allocated three frequency bands, namely, 3,000–3,246 megacycles, 9,320–9,500 megacycles, and 5,460–5,650 megacycles for shipboard radar with adjacent bands for racon (radar beacon). Commercial type merchant marine radar equipment is available in the first two bands and many experimental licenses already have been issued for use. Proponents of radar in the lower frequency band claim a superior ability to distinguish targets in all kinds of weather. Advocates of radar in the high band claim superior definition and increased dependability for navigating through narrow channels. Equipment for the third band is not generally available; the Commission allocated this band, in addition to the other two, to provide an opportunity to determine whether it might combine the advantages claimed for the other two bands. At the present time licenses for radar are issued on an experimental basis and for a term of one year, but 5-year licenses will be issued on a regular basis for operation of acceptable shipboard radar as soon as rules and regulations can be prepared and promulgated by the Commission.

FAITH OF THE ENGINEER

I AM AN ENGINEER. In my profession I take deep pride, but without vainglory; to it I owe solemn obligations that I am eager to fulfill.

As an Engineer, I will participate in none but honest enterprise. To him that has engaged my services, as employer or client, I will give the utmost of performance and fidelity.

When needed, my skill and knowledge shall be given without reservation for the public good. From special capacity springs the obligation to use it well in the service of humanity; and I accept the challenge that this implies.

Jealous of the high repute of my calling, I will strive to protect the interests and the good name of any engineer that I know to be deserving; but I will not shrink, should duty dictate, from disclosing the truth regarding anyone that, by unscrupulous act, has shown himself unworthy of the profession.

Since the Age of Stone, human progress has been conditioned by the genius of my professional forbears. By them have been rendered usable to mankind Nature's vast resources of material and energy. By them have been vitalized and turned to practical account the principles of science and the revelations of technology. Except for this heritage of accumulated experience, my efforts would be feeble. I dedicate myself to the dissemination of engineering knowledge, and, especially to the instruction of younger members of my profession in all its arts and traditions.

To my fellows I pledge, in the same full measure I ask of them, integrity and fair dealing, tolerance and respect, and devotion to the standards and the dignity of our profession; with the consciousness, always, that our special expertness carries with it the obligation to serve humanity with complete sincerity.

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More Lighting Needed in United States

According to Doctor A. M. Dickerson, manager of the General Electric lighting division, 50,000 miles of traffic street lighting and extensive lighting on residential streets are required to provide adequate traffic safety lighting of United States streets and highways. Less than two per cent of the municipal tax dollars now go for street lighting, says Doctor Dickerson. Other municipal services have increased from 200 to 300 per cent but street lighting expenditures have remained the same. Meanwhile, traffic deaths have increased 25 fold.

Citing the case of New Jersey, he indicates that state aid may be the solution to the problem particularly for small communities. The State of New Jersey pays the private utility companies for a 2,500-lumen lamp in a modern luminaire for each 200 feet of state designated highway within the corporate limits of towns, villages, and cities making application for such aid. More lighting than this usually is used and the excess cost is borne by the local community. The state wholly finances large quantities of continuous highway and intersection lighting outside of urban limits.

He pointed out that the new edition of the Illuminating Engineering Society's recommended practice of street lighting is rapidly becoming the accepted standard of street lighting practice in most United States cities. Pendant luminaires are specified exclusively because they provide from two to three times as much light on the pavement as the commonly used upright globes and lanterns. In addition to its main function of reducing accidents and facilitating traffic, Doctor Dickerson claims that good lighting is instrumental in reducing crime, aiding police and firemen, improving business, increasing property values, and enhancing civic prestige.

Microwave Equipment in Central America. Compania Radiografica Internacional de Costa Rica, an affiliate of the Tropical Radio Telegraph Company has obtained from Raytheon Manufacturing Company the first microwave radio communications equipment to be installed in Central America. A postwar modernization program involving the utilization of frequency shift printer circuit and diversity reception is now going on. A new transmitting station is being built at Las Pavas, about five miles from the capital city of San Jose. The transmitters will be connected to the central operating offices in San Jose through the new microwave link, which will replace all wire lines. The microwave link will carry multiplex telegraph and telephone channels operating simultaneously. The microwave equipment operates at 4,000 megacycles utilizing a 50-watt continuous-wave-type magnetron. This installation in Costa Rica will be regarded with much interest by operating companies elsewhere in Latin America in view of the similarity of conditions.

Product Design Contest Resumed. The publishers of *Electrical Manufacturing*, New York, N. Y., announce the resumption of their annual product design contest, a yearly event until the war interrupted. Cash awards totaling $2,500 will be made for excellence in design and achievement in engineering of new electrically operated machines, appliances, or equipment. This, the ninth annual contest, closes August 6, and manuscripts describing the development of the award winning products will be published in the October product design issue of *Electrical Manufacturing*.

P. B. Taylor to Sanderson and Porter. Admission to partnership of Philip B. Taylor has been announced by Sanderson and Porter, 50-year-old firm of engineers and constructors. Taylor, former chief engineer and then vice-president and general manager of the Wright Aeronautical Corporation and now president of Taylor Turbine Corporation, brings to his new connection a broad experience as an engineer and executive director of a large technical organization.

Jefferson Electric Chairman Dies. John A. Bennan, chairman of Jefferson Electric Company, Norwood, Ill., died April 17, at St. Lukes Hospital Chicago, Ill. He helped establish the company in 1915. He was also a past member of the board of directors of the National Electrical Manufacturers Association.

Electronics Fellowship. A number of graduate and advanced research fellowships are offered by the Massachusetts Institute of Technology, Cambridge, Mass., for study and research in the field of electronics. In addition to the fellowships having $1,200 to $1,500 stipends, a few advanced research fellowships carrying stipends of $2,000 to $3,000 will be awarded to candidates possessing graduate academic degrees or equivalent research experience. Applicants should communicate with J. A. Stratton, director, Research Laboratory of Electronics, Massachusetts Institute of Technology, Cambridge. Under normal circumstances, application must be made at least four months prior to the intended date of entrance.

Electric Tractor in Russia. Electric traction for agriculture is becoming a concrete prospect for Soviet collective farmers with machines being put through their field tests and orders placed for the first trial lot. Experimental machines built by the Moscow Institute for Mechanization in Electrification of Agriculture are claimed to have passed successfully lengthy, preliminary tests. The tractor is mounted on an ordinary chassis with ordinary transmission and traction gear. The 54-horsepower electric motor is supplied by a 750-meter (2,460-foot) cable rolled on and paid out from a drum installed on the machine. Tractor speed ranges from 2.7 to 3.9 miles per hour with productivity at an average of 2 to 2.5 acres of plowing an hour at a power consumption of approximately 18.6 kilowatt-hours per acre. According to Russian agricultural experts, cost of electric tractor operation is almost half that of combustion engine tractors, and electric traction will make for deeper plowing and greater efficiency at other stages of cultivation.

Former Radar Chief Decorated. George F. Metcalf, manager of General Electric Electronics Laboratory at Syracuse, N. Y., former head of the Aircraft Radar Laboratories at Wright Field, Ohio, has been appointed an honorary officer of the Military Division of the Most Excellent Order of the British Empire for his wartime contributions to air-borne radar. The citation accompanying the decoration read: "Colonel Metcalf was associated with air-borne radar, first in the War Department and later at the Aircraft Radar Laboratories. Due to his enthusiasm and engineering appreciation, collaboration on detailed aspects of development or design of air-borne radar equipment, was effective in making an important contribution to the air war."

RESEARCH ● ● ● ●

Research Board Organizes Committee

The recently established Joint Research and Development Board under the direction of Doctor Vannevar Bush (F '24) has organized a number of technical committees to study existing Army and Navy research projects. The committees will function first in an advisory capacity. However, it is expected that they will increase in power, and that some military projects may be revaluated.

The committee on electronics is headed by Doctor J. A. Stratton, director of the research laboratory of electronics at Massachusetts Institute of Technology, and will have such special panels as radar, communications, and countermeasures. Other committee heads are: atomic energy—Doctor J. B. Conant, president of Harvard University, Cambridge; guided missiles—Doctor Karl T. Compton (F '31) president of Massachusetts Institute of Technology, Cambridge; geophysical sciences—Doctor R. F. Beers, president, Geotechnical Corporation, Dallas, Texas; geographical exploration—Doctor C. H. Behre, Jr., professor of geology, Columbia University, New York, N. Y.

Future Meeting of Other Societies

American Society of Civil Engineers. Fall meeting October 15–18, 1947, New Orleans, La.

American Society of Tool Engineers. 16th annual meeting and tool exhibition, March 15–19, 1948, Cleveland, Ohio.

American Society of Mechanical Engineers. Fall meeting, September 1–4, 1947, Salt Lake City, Utah, annual meeting, December 1–5, 1947, Atlantic City, N. J.

American Standards Association. Annual meeting, October 21–23, 1947, New York, N. Y.

American Welding Society. Annual meeting, October 20–24, 1947, Chicago, Ill.

Association des Ingénieurs. Centenary congress and exhibition, August 30–September 13, 1947, Liége, Belgium.

Canadian Institute of Radio Engineers. Convention, April 30–May 1, 1948, Toronto, Ontario, Canada.

CIGRE (International Conference on Large Electric High-Voltage Systems). Biennial meeting, June 24–July 3, 1948, Paris, France.

Cold Cathode Fluorescent Lighting. First annual exhibit, October 7–9, 1947, New York, N. Y.

Exposition of Chemical Industries. 21st annual exposition, December 1–5, 1947, New York, N. Y.

Fluorescent Lighting Association. Annual meeting, April 15, 1948, New York, N. Y.

Illuminating Engineering Society. Annual convention, September 15–19, 1947, New Orleans, La.

Institute of the Aeronautical Sciences. Annual meeting, August 7–8, 1947, Los Angeles, Calif.

Instrument Society of America. Second annual conference and exhibit, September 8–12, 1947, Chicago, Ill.

International Lighting Exposition and Conference. November 3–7, 1947, Chicago, Ill. Sponsored by National Electric Manufacturers Association.

International Municipal Signal Association, Inc. 52d annual meeting, September 29–October 2, 1947, Grand Rapids, Mich.

National Association of Manufacturers. 52d Annual Congress of American Industry, December 3–5, 1947, New York, N. Y.

National Electrical Contractors' Association. 46th annual meeting, September 8–10, 1947, San Francisco, Calif.

National Electric Manufacturers Association. October 27–31, 1947, Atlantic City, N. J.; winter convention, March 14–18, 1948, Chicago, Ill.

National Electronics Conference. November 3–5, 1947, Chicago, Ill.

National Safety Congress and Exposition. 35th annual meeting, October 6–10, 1947, Chicago, Ill.

Pacific Chemical Exposition and Pacific Industrial Conferences. October 21–25, 1947, San Francisco, Calif.

Refrigeration Equipment Manufacturers Association. All-Industry Refrigerating and Air-Conditioning Exposition. January 26–29, 1948, Cleveland, Ohio.

Society of Automotive Engineers. Annual meeting, January 12–16, 1948, Detroit, Mich.

World Power Conference. Fuel economy conference, September 2–9, 1947, The Hague, Netherlands.

High-Speed Motors Built for Research

Among special motors now being built by the General Electric Company, Schenectady, N. Y., for research purposes are three rated 0.1 horsepower at 80,000 rpm. The motors will be only $1^3/_4$ inches in diameter and 6 inches long. The squirrel cage, which is on the outside, will form the rotor. The shaft and the "rotor," which carries the primary 3-phase winding, will be stationary and will form the motor support.

Other unusual special motors under construction at the Schenectady works are two 700-horsepower and two 300-horsepower motors which will operate at 18,000 rpm. These are 4-pole 600-cycle units, and will be provided with hollow stator conductors in which water will be circulated to remove the heat losses. The shells also will be water cooled to assist in removing the losses in the stator iron.

The 700-horsepower motors will be 14 inches in diameter by 24 inches long over the shell. The 300-horsepower motors will be 10 inches in diameter by 22 inches over the shell.

Jewett Fellowships Awarded for 1947-48

Award of seven Frank B. Jewett fellowships for research in the physical sciences has been announced by the American Telephone and Telegraph Company which founded the grant in 1944 upon Doctor Jewett's retirement as vice-president of the company.

The recipients this year are Doctor M. G. Ettlinger, a winner last year, and W. D. Hayes, both of the California Institute of Technology; Paul Olum, Harvard University; Aadne Ore, Yale University; Doctor Alfred Schild, Carnegie Institute of Technology; Doctor R. L. Scott, University of California, also a 1946–47 winner; and E. H. Spanier, University of Michigan.

The awards carry an annual stipend of $3,000 to the holder and $1,500 to the institution at which the recipient elects to do research. Principal criteria used in selecting the recipients are: demonstrated research ability, the fundamental importance of the problem to be attacked, and the likelihood of the individual's growth as a scientist.

LETTERS TO THE EDITOR

INSTITUTE members and subscribers are invited to contribute to these columns expressions of opinion dealing with published articles, technical papers, or other subjects of general professional interest. While endeavoring to publish as many letters as possible, Electrical Engineering reserves the right to publish them in whole or in part or to reject them entirely. Statements in letters are expressly understood to be made by the writers. Publication here in no wise constitutes endorsement or recognition by the AIEE. All letters submitted for publication should be typewritten, double-spaced, not carbon copies. Any illustrations should be submitted in duplicate, one copy an inked drawing without lettering, the other lettered. Captions should be supplied for all illustrations.

That "Place in the Sun" for Engineers

To the Editor:

After reading the many statements drawn up by representatives of various engineering groups complaining that management in general has failed to recognize and therefore to compensate engineers as a whole commensurate with the responsibilities imposed upon them, it seems to me that one factor having considerable bearing on the situation has not been discussed—What part of the blame for this situation should be shouldered by the engineers themselves?

In the 28 years I have served as a secretary of the board of examiners of AIEE, I have had to review personally some 14,000 applications for admission and transfer to Member and Fellow grades. In addition about 42,000 Associate applications have come before the examiners during my secretaryship. All in all, that constitutes a pretty good sampling of the electrical profession. As a result of this composite of the electrical engineers accomplishments and idiosyncrasies, I have come to the sad conclusion that in spite of a record of accomplishment second to none, engineers as a whole are poor salesmen of their own important services.

Whether this fault is due to lack of proper basic training in certain fields, or to something inherent in the makeup of the men who take up engineering as a life work, is open to argument. Perhaps it is due to innate modesty. Whatever it is, it quite frequently results in the AIEE board of examiners, a group not governed in their decisions by economic considerations, being unable to determine from data originally submitted by applicants, fitness for the standing sought in their own national society. Many times it is necessary to go back again and again, painfully to draw out the data that should have been given in the first place. Eventually it becomes evident that applicants are really well qualified. That this situation is not due to any lack of interest in the outcome is proved by the reactions when the examiners' decisions based on facts submitted are unfavorable.

Again (and I am speaking now from close contact with the planning of New York Section meeting programs since 1919) anyone who has been faced with the problems of setting up meetings where speakers are to present popular presentations on subjects of great general interest value will testify to the difficulty of locating such speakers. While there is no lack of men fully posted on every technical detail, few can present the facts in a convincing and interesting way. There have been several fairly recent examples of this situation. The engineers, with every fact at their fingertips, nearly put the audience to sleep. They were followed by a nontechnical man, in one case a lawyer, who had drawn all his facts from the engineers. His review, I believe, resulted in preventing many in the audience from considering the meeting a total failure.

Based on these contacts with the electrical engineer therefore it seems to me quite likely that the characteristic or weakness I have cited, may have considerable bearing on the fact that engineers do not hold what they feel to be their rightful place in management. There are of course certain notable exceptions. However, as long as management remains predominantly in the control of lawyers, bankers and other nontechnical men interested largely in operating at minimum cost, the engineering staff will be relegated to the back seats. Only when that staff, individually and collectively, can stand on their feet and effectually argue problems with the bankers and lawyers, prove their right to control and direct, will the engineer in general eventually take over his "Place in the Sun". No complicated plans, *A*, *B*, *C* or *D*, no super grouping of societies, will solve the problem, unless engineers want to use the pressure tactics of labor unions. I do not believe they do.

What I would say is needed is far more training in public speaking, in management, in economics, and in the proper and effective use of the English language. It will take time. In my opinion it is the only way of reaching the goal so many are seeking by means of devious organization plans.

HENRY E. FARRER (M '46)

(Secretary, board of examiners, AIEE)

IBM Calculator

To the Editor:

In your section "Of Current Interest" in *ELECTRICAL ENGINEERING* for April 1947, in the article on the new calculator at Harvard University on page 416, you make reference to the "Mark I" which is erroneous.

The IBM automatic sequence controlled calculator, referred to in your article as "Mark I," was built by International Business Machines Corporation at our plant at Endicott, N. Y., beginning in 1939 and continuing until August 1944, when it was presented as a gift to Harvard University by our company, as was correctly stated in the footnote to your original article last August (*EE, Aug-Sept '46, pp 384–91*).

Our part in the design, development, and construction of this machine has been overlooked or erroneously stated so widely that we feel that the record should be put straight. In fact, it is repeated in Doctor E. U. Condon's article, "Electronics and the Future," (page 355) in this same issue of *ELECTRICAL ENGINEERING.* We would appreciate anything you can do to put the facts straight.

J. C. McPHERSON

(Patent research and development manager, International Business Machines Corporation, Endicott, N. Y.)

Forces Between Moving Charges

To the Editor:

Captain E. G. Cullwick in his interesting letter (*EE, May '47 pp 518–9*) voices the very reasonable expectation that the influence of one electric system upon another, will depend only on the relative velocity of the two systems, and not on any "absolute" velocity which may be assigned to either system. No doubt this is true, in a sense which requires careful definition.

However, it is not true that the *description* which an observer will give, of the influence of the one system upon the other, will depend only on the relative velocity of the two systems. It will depend also on the velocity of either system relative to the observer. This is because the observer describes his observation in terms of concepts whose definitions are relative to him.

Thus the observer defines the electric field at a point, as the force per unit charge on a charged body at *rest* relative to him at that point. He will also define the magnetic field, through the effects observed on a charged body, or on a probe coil, moved in some prescribed manner *relative* to him. Another observer, however, in motion relative to the first observer, in observing the electromagnetic field, will define the electric field at a point as the force per unit charge on a charged body at rest *relative* to him, and therefore in motion relative to the other observer. Similarly, with respect to the magnetic field. Thus, the electric and magnetic fields, in their very definition are relative to the observer, and the two observers, in our case, will not "see" the same electric and magnetic fields.

This relativity of the electric and magnetic fields with respect to the observer, arises not only from the relativity of the motion of the probes and probe coils used in the definition of the fields, but also from the relativity of the concept of force used in the definitions. Each observer will probably define force through some observation of the acceleration given to a particle of known mass. However, each observer, in measuring mass, will use a standard in a laboratory at rest *relative* to him, and in measuring acceleration, will use meter sticks and clocks at rest *relative* to him and in motion *relative* to the other observer. Hence, the concept of force which enters into the definition of the electric field, will also be relative to the observer.

Thus we find, as Captain Cullwick points out, that the electric and magnetic fields around a point charge, for an observer for whom the charge is at rest, are different from the electric and magnetic fields for an observer for whom the charge is moving.

One can hardly disagree with Captain Cullwick, that if absolute velocity is to have no meaning in nature, then the influence of one system upon another must depend only on their relative velocity. But this does not mean that the description of this influence as given by all observers will depend only upon this relative velocity of the two systems. We require only that these various descriptions shall be accounted for by taking account of the relativity of the concepts occurring in the various observers' descriptions, that is, that different probe charged bodies, probe coils, meter sticks, clocks, and so forth, are used by the different observers, in giving their descriptions of the influence of the one system on the other.

Captain Cullwick takes as his two systems, a coil, and a system of charges on a rigid body, in relative motion. For an observer for whom the system of charges is at rest, Captain Cullwick states that the integral of electric force along the wires of the coil is zero. For an observer for whom the coil is at rest, the integral of electric force along the wires of the coil is not zero. There is no contradiction in this. Each observer is able to account for the other's result by the different probe bodies, mass unit, meter sticks, and clocks which the other uses.

J. SLEPIAN (F '27)

(Associate director, research laboratories, Westinghouse Electric Corporation, East Pittsburgh, Pa.)

To the Editor:

Reference is made to an article entitled "The Forces Between Moving Charges" by R. D. Sard, which appeared in the January 1947 issue of *ELECTRICAL ENGINEERING*, in which reference is made to an earlier article written by me (*EE, Oct '45, pp 351–6*). Professor Sard contends that my analysis proposes a drastic modification of electromagnetic theory, but it is worthy of note that he does not attempt to impeach the correctness of the results obtained by my methods. Indeed, he presents a lengthy demonstration to prove that for the case of charges moving parallel, line abreast, the textbook formulas yield the same results given by my formulas.

In writing the article to which Professor Sard refers I was under the impression that I was merely reviewing some of the basic concepts of electromagnetism in the light of prevailing thought, and offering a means for the practical engineer to bridge the gap between the two. Consequently, I have been somewhat surprised at the controversy which the article has aroused. While the most satisfactory reply would be to show the innumerable ways in which the analysis given in my article proves itself out, this would require an amount of demonstration and mathematical proof out of place in a communication of this character. Therefore I shall limit my remarks to matters related directly to the subject of Professor Sard's article, with the object of demonstrating the following:

1. There is not so much difference between my formulas and the textbook formulas as might appear from a casual review.
2. My formulas are closer to Maxwell's teachings than are the textbook formulas.
3. The differences between my formulas and Maxwell's teachings are in accord with precepts taught by the current textbooks.
4. It is widely recognized that the textbook formulas give incorrect or inconsistent results in many cases.

In the case of two charges moving line abreast, assume that the first charge is located at point $x=0$, $y=y$, $z=0$, with the other at the origin of co-ordinates. Professor Sard's equation 3*a* then reduces to a single component of force, which is in the y direction and equal to $F_{y2}=-e_1e_2(1-\beta_1\beta_2)/y^2\sqrt{1-\beta_1^2}$. Now, if the observer measures β_1 and β_2 equal in magnitude and in the same direction parallel to the x axis, this reduces to $F_{y2}=-e_1e_2\sqrt{1-\beta_x^2}/y^2$. But if the observer should attempt to transport his mental processes into the reference system of the second charge, which is also the reference system of the first charge since $\beta_2=\beta_1=\beta_x$, he knows from electrostatics that he would measure the force as $F_{y2}=-e_1e_2/y^2$ and is forced to introduce the concept of variable mass with respect to his own system, as Professor Sard has done in order to make his kinematic equations come out right.

However, there is available to the observer a simpler process which Professor Sard seems to have overlooked. He can use the transformation equations to relate E and H as measured in his own reference system to their values in the reference system of the charge on which the force is to be determined. In his own system the observer measures the velocities of the two charges as β_1 and β_2 and the electric and magnetic fields, according to Professor Sard's equation 1 for the conditions stated, as

$$
\begin{aligned}
E_x&=0\\
E_y&=-e_1/y^2\sqrt{1-\beta_1^2}\\
E_z&=0\\
H_x&=0\\
H_y&=0\\
H_z&=-\beta_1e_1/y^2\sqrt{1-\beta_1^2}
\end{aligned}
$$

Transferring these field terms to the reference system of the second charge, according to the transformation equations as given by Page and Adams[1], yields:

$$
\begin{aligned}
E_{x2}&=0\\
E_{y2}&=-(1-\beta_1\beta_2)e_1/y^2\sqrt{1-\beta_1^2}\sqrt{1-\beta_2^2}\\
E_{z2}&=0\\
H_{x2}&=0\\
H_{y2}&=0\\
H_{z2}&=-(\beta_1-\beta_2)e_1/y^2\sqrt{1-\beta_1^2}\sqrt{1-\beta_2^2}
\end{aligned}
$$

Putting these values in Professor Sard's equation 2 yields a single component of force, which is in the y direction and equal to:

$$F_{y2}=-\frac{(1-2\beta_1\beta_2+\beta_2^2)e_1e_2}{\sqrt{1-\beta_1^2}\sqrt{1-\beta_2^2}\,y^2} \tag{1}$$

When $\beta_1=\beta_2=\beta_x$ this reduces to $F_{y2}=-e_1e_2/y^2$ just as though the second charge were at rest in the system of the first charge, which is my contention exactly.

It is to be noted that my article dealt with force effects as related to motion, which may be considered as the full electromagnetic effect. Professor Sard's analysis, following the usual textbook technique, combines the electrostatic and electromagnetic forces in the one formula. Any comparison with my formulas is to be made only with respect to terms in the combined formulas which contain β in any form. This is in accordance with the generally accepted concept that magnetism is a dynamic phenomenon, one of motion. To quote Maxwell,[2] "According to our hypothesis, we assume the kinetic energy to exist wherever there is magnetic force..." and "...this energy exists in the form of some kind of motion of the matter in every portion of space."

Since Professor Sard offers Maxwell as a background to his analysis, a few comments should be in order showing that my analysis follows Maxwell with very little change. In the first place, Maxwell based his development of electromagnetism on Ampère's work. In Chapter II of Section IV of his "Treatise" he gives an extensive discussion of Ampère's work, including Ampère's formulas for the interaction of currents. The basic formula for the force between current elements, as given by Ampère[3] and described by him as fundamental to his entire theory, is $F=ii'\,ds\,ds'(\sin\theta\sin\theta'\cos\omega+k\cos\theta\cos\theta')/r^2$ with a value of $-{}^1/_2$ for k. Recognizing the relation between $i\,ds$ and the quantity and velocity of the electricity making up a flow of current, this formula can be written: $F=QQ'(v\sin\theta\,v'\sin\theta'\cos\omega-{}^1/_2\,v\cos\theta v'\cos\theta')/r^2$, in which form it will be recognized as equivalent to equation 4 in my article except that I use the squares of relative velocity components instead of the products of individual velocity components. Maxwell claimed[4] that Ampère's formula required a factor of two for use in electromagnetic units, as Ampère used electrodynamic units. This undoubtedly is true, but does not apply to my formulas, as it is to be noted that in the days of both Ampère and Maxwell, as the latter admits,[5] it was not known whether a flow of current was more correctly treated in terms of the 1-fluid theory or the 2-fluid theory. Any formula designed for application to both positive and negative electricity combined, even though one kind is "bound" as we now consider the positive to be, should be expected to give twice the value given by formulas, such as mine, which treat the two kinds individually. When the results are summed up for the total of the two effects, as explained in my article and also used by Professor Sard, the two procedures become equivalent.

Utilization of the relative velocity as employed in my article, instead of the individual velocities of the current elements, is in accordance with prevailing concepts and may be considered a "modernization" of Ampère which is no more to be criticized than the Lorentz transformation, and, indeed, has been shown to be equivalent thereto in the case just investigated. Maxwell's "Treatise" abounds with references to relative motion. Modern textbooks introduce it through the concept that the field of a charge is carried along with the charge. For this I quote Page[6] and Richtmyer and Kennard,[7] the latter even amplifying to the extent of stating: "...relative to the charge the field seems to stand still." This is in conformity with the principle that the laws of nature are the same in any inertial system. Certainly, in accordance with this, the conditions when all charges have a common velocity must be the same as for static conditions. Professor Sard agrees with this. Then it follows that when the velocities are not the same the effects must depend upon the difference of the velocities. Of course I have not combined my velocities in a relativity manner. This does not seem to be necessary, but I see no objection to doing so if it gives the user more esthetic satisfaction.

The textbook formulas make a much more radical departure from Maxwell's teachings than any which I have discussed, in that they use Biot's law for the electromagnetic effects of current flow. Actually it is commonly believed that it is Ampère's law which is being used. Page[8] makes this misstatement, as do others, including Jeans.[9] In a recent article[10] in *ELECTRICAL ENGINEERING*, describing the method of teaching electricity and magnetism in the University of Kansas, the same historical error is made. This error has been pointed out by a number of sources.[11,12,13] While historical accuracy is not essential to scientific accuracy it frequently is helpful to a proper grasp of the significance of the ideas of past authorities. In this instance I believe that the introduction of Biot's formula, instead of Ampère's, as intended by Maxwell, is at the root of the present controversy. Maxwell seems to have discounted Biot's work rather completely. I have not noted in his "Treatise" a single direct reference to either Biot or Savart.

Use of Biot's formula leads to results which are inconsistent with the third law of motion (equality of action and reaction). This has been recognized widely, and has been the subject of a number of articles.[13,14,15] However, none of these references resolves the problem as completely and simply as does a straightforward application of my formulas. Robertson goes back to Ampère but does not employ the relative velocity concept. Howe attempts to reintroduce Maxwell's now outmoded displacement currents in free space. Both arrive at conclusions which should be recognized at once by any electrical engineer as contrary to the facts in generator and motor operation. Keller introduces the concept of the momentum of the field as expounded by J. J. Thomson,[16] but he uses formulas for E and H which, while purporting to be the same as the textbook formulas, actually differ from those in general use by a factor of $1-\beta^2$ although they appear at first glance to be equivalent but in slightly different form. This tends to cast doubt upon the correctness of his entire analysis.

It is worth noting that Maxwell repeatedly points out the usefulness of a close adherence to Ampère's analysis. For instance, following a comparison of possible formulas for the interaction of current elements, he concludes with this statement:[17] "Of these four different assumptions that of Ampère is undoubtedly the best, since it is the only one which makes the force on the two elements not only equal and opposite but in the straight line which joins them." This is a strikingly significant statement, and gives an unequivocal interpretation of the mental picture he had as he started upon the development of his field theory.

It even might be inferred that Maxwell felt impelled to utter a word of caution against breaking too far away from Ampère in the application of the field equations to individual charges. For after developing his field theory, we find he reverts to Ampère, repeating a thought previously mentioned in the course of his field development, in these terms:[18] "If we suppose our mathematical machinery to be so coarse that our line of integration cannot thread a molecular circuit, and that an immense number of magnetic molecules are contained in our element of volume, we shall still arrive at results similar to those of Part III, but if we suppose our machinery of a finer order, and capable of investigating all that goes on in the interior of the molecules, we must give up the old theory of magnetism, and adopt that of Ampère, which admits of no magnets except those which consist of electric currents."

Finally it seems worth while to point out that the writer's formulas, when put in vector form and combined with the Coulomb electrostatic force become:

$$F=e_1e_2\left[\frac{R}{r^3}+\frac{Rv^2}{c^2r^3}-\frac{3}{2}\cdot\frac{R(V\cdot R)^2}{c^2r^5}\right] \qquad (2)$$

where

R = the vector distance between the charges
r = the scalar magnitude of R
V = the vector velocity difference of the charges
v = the scalar magnitude of V
c = the ratio of electromagnetic to electrostatic units
e_1, e_2 = the magnitudes of the charges
(All terms in centimeter-gram-second electrostatic units)

This formula follows from the work of Wilhelm Weber, published in 1846–48, and discussed at some length in the concluding chapter[19] of Maxwell's "Treatise." It is worthy of note that Maxwell admits the correctness of the results obtained by Weber's analysis, but rejects the method largely because it either did not require a medium or seemed to require instantaneous transmission in a medium. But it now appears that for unaccelerated charges (the case under discussion) the question of transmission does not enter, because if we accept, along with references quoted, the idea that "the field is carried along with the charge," then the effect of the velocity is uniformly present everywhere simultaneously. Of course if accelerations occur, a term for the acceleration effect must be added, and for large distances of separation the method of retarded potentials must be used. But this is only what should be expected, in accordance with the commonly accepted principle that radiation is produced only by accelerated charges.

This brings up a point which, while not specifically pertinent to the present discussion, is so fundamental and so generally misunderstood that it seems advisable to conclude with a few remarks concerning it. This is the fact that in electromagnetism there are two distinct processes: the one an effect due to the relative velocities of the charges, usually revealing itself as physical forces, as in the "motor" effect, but also frequently revealing itself as a voltage, as in the "generator" effect; and the other an effect due to the relative accelerations of the charges, usually revealing itself as an induced voltage, as in the "transformer" effect. . . . But the distinction between the effects of uniform velocities and changing velocities is not made clear in most textbooks. Even Maxwell does not draw a clear line of distinction in these matters. He discusses electromagnetism with respect to the work of Ampère and Faraday more or less correlatively, without seeming to realize that the former's discoveries were related mostly to the "motor" effect and the latter's mostly to the "transformer" and "generator" effects. It probably is due to the fact that two effects were discovered by the one individual and, especially, within a few days of each other that the distinctions as to causation have not become recognized generally. . . .

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WILLIAM A. TRIPP (M '35)

(Electrical engineer, engineering department, Charles T. Main, Inc., Engineers, Boston, Mass.)

Transmission Line Impedance Calculations

To the Editor:

In the usual method of calculating the attenuation function of a line, the series impedance per unit length, $\mathcal{Z}\underline{/\theta_Z}$, and the shunt admittance per unit length, $Y\underline{/\theta_Y}$, first are determined. The propagation function per unit length, $\gamma\underline{/\theta_\gamma}$, is the square root of the product of these quantities. The real part of the propagation function is the attenuation function, α, and the imaginary part is the phase function, β.

For accuracy in the third significant figure in determining α, it frequently is found necessary to carry θ_Y and θ_Z to 1/100 of a degree, while in the determination of β, a degree change in θ_Y or θ_Z will not affect the value appreciably. This is because θ_γ is close to 90 degrees where the cosine is changing rapidly with the angle, and the sine is not.

As an example, consider the following case. A carrier cable, operated at 50,000 cycles per second, has the following constants per loop foot: $C=25.31$ micromicrofarads, $L=0.130$ microhenry, $R=0.00444$ ohm, and $G=0.0628$ micromho. Calculation gives

$$Y=(7.95\times10^{-6})\underline{/89.55^\circ}$$

$$\mathcal{Z}=0.0409\underline{/83.78^\circ}$$

from which

$$\gamma=(0.571\times10^{-3})\underline{/86.67^\circ}$$

and

$$\alpha+j\beta=(0.0332+j0.569)\times10^{-3}$$

If one takes

$$Y=(7.95\times10^{-6})\underline{/90^\circ}$$

and

$$\mathcal{Z}=0.\underline{0409}/84^\circ$$

γ becomes

$$\gamma=(0.571\times10^{-3})\underline{/87^\circ}$$

and

$$\alpha+j\beta=(0.0299+j0.569)\times10^{-3}$$

The error in α is about ten per cent, but the value of β is unchanged.

In the same way, the real part, R_k, of the characteristic impedance, $\mathcal{Z}_k\underline{/\theta_k}$, usually may be calculated with small error without great accuracy in θ_Y and θ_Z, but the reactive component, X_k, may require more care. In the foregoing case

$$\mathcal{Z}_k=71.8\underline{/-2.88^\circ}$$

and

$$R_k+jX_k=71.7-j3.61$$

Rounding of the angles to 90 and 84 degrees gives

$$R_k+jX_k=71.7-j3.76$$

causing an error of about four per cent in X_k.

In making these calculations with a slide rule, the determination of angles near 90 degrees to 1/100 of a degree is inconvenient. A pair of formulas which are convenient to use and which yield good accuracy are as follows:

$$\alpha=\frac{G\mathcal{Z}_k^2+R}{2R_k} \tag{1}$$

and

$$X_k=\frac{G\mathcal{Z}_k^2-R}{2\beta} \tag{2}$$

Since R_k, $\mathcal{Z}_k$, and β may be determined accurately without great accuracy in θ_Y and θ_Z, these two formulas may be used to determine α and X_k accurately when θ_Y and θ_Z are only approximate values. In the foregoing example, if the approximate values $\theta_Y=90^\circ$ and $\theta_Z=84^\circ$ are used, $\mathcal{Z}_k=71.8$, $R_k=71.7$, and

$$\alpha=\frac{(0.0628\times10^{-6}\times5150)+0.00444}{143.4}$$
$$=0.0332\times10^{-3}$$

Similarly the value of X_k is found to be -3.62. These errors are well within the limits of slide rule accuracy.

It should be pointed out that these formulas for α and X_k reduce, at high frequency, to the well-known formulas for this case. For high frequencies, $\mathcal{Z}_k=R_k$, and α becomes $(R/2\mathcal{Z}_k)+(G\mathcal{Z}_k/2)$; X_k becomes zero because β becomes large.

Proof of the formulas is as follows:

$$\begin{aligned}\gamma&=\alpha+j\beta\\&=\sqrt{Y\mathcal{Z}}\ \underline{\bigg/\frac{\theta_Z+\theta_Y}{2}}\\&=\sqrt{Y\mathcal{Z}}\cos\left(\frac{\theta_Z+\theta_Y}{2}\right)+\\&\qquad j\sqrt{Y\mathcal{Z}}\sin\left(\frac{\theta_Z+\theta_Y}{2}\right)\end{aligned} \tag{3}$$

and

$$Z_k = R_k + jX_k$$

$$= \sqrt{\frac{Z}{Y}} \angle \frac{\theta_Z - \theta_Y}{2}$$

$$= \sqrt{\frac{Z}{Y}} \cos\left(\frac{\theta_Z - \theta_Y}{2}\right) + j\sqrt{\frac{Z}{Y}} \sin\left(\frac{\theta_Z - \theta_Y}{2}\right) \quad (4)$$

Multiplying twice α by R_k

$$2\alpha R_k = 2Z\left[\cos\left(\frac{\theta_z + \theta_Y}{2}\right)\right]\left[\cos\left(\frac{\theta_z - \theta_Y}{2}\right)\right]$$

$$= Z(\cos \theta_Z + \cos \theta_Y) \quad (5)$$

Now $\cos \theta_Y = G/Y$, and $\cos \theta_Z = R/Z$, so

$$2\alpha R_k = R + \frac{ZG}{Y}$$

$$= R + GZ_k^2 \quad (6)$$

from which equation 1 follows. In an exactly similar manner, from the values of β and X_k in equations 3 and 4, equation 2 may be found.

E. W. HAMLIN (M '42)

Professor of electrical engineering, University of Texas, Austin)

R. A. GALBRAITH (A '38)

[Electrical engineering department, Syracuse (N. Y.) University]

Correspondents Wanted

To the Editor:

Can you please ask any member of the Institute who is willing to find a correspondent in Malta to start writing to me. I shall be glad to exchange views with any American engineer.

ART ROEBUCK (A '47)

(45 New Street, Msida, Malta)

Dielectric Strength

To the Editor:

The paper, "Dielectric Strength of Station and Line Insulation to Switching Surges" by P. L. Bellaschi and L. B. Rademacher (*AIEE TRANSACTIONS, volume 65, 1946, pages 1047–54*) is a valuable contribution in the field of insulation co-ordination on transmission lines and major station equipment as a first step in bringing together a large part of available data on the relative importance of switching surges. Field studies on the characteristics of natural lightning and accompanying laboratory research and practical testing of equipment with surge or lightning voltages have made available sufficient impulse data on the subject to design electric systems which are highly resistant to surge voltages of the lightning type.

The question often has been raised in the minds of some in the industry as to the adequacy of insulation in various parts of the system when subjected to switching surges which are fairly numerous on any transmission system today. Only rather incomplete and sketchy data have been available on the subject. But as its importance seems due to increase with the prospect of higher voltage lines, and with the necessity of utilizing insulation more efficiently in order to bring down the cost of equipment, the necessity for better understanding the characteristics of switching surge voltages and their effect on insulation is becoming a problem of major importance.

The wave shapes for test purposes used by the authors appear from the oscillograms to have a shape of approximately an 800-microsecond front and a 2,000-microsecond duration. Whether these cover the outside ranges of wave shapes encountered in switching surges may well be questioned. Until the limiting values of these ranges have been determined more definitely, some caution is urged in attempting to utilize insulation of equipment at a value too close to its ultimate strength.

The general conclusion the authors draw in the paper is that the switching surge strength of equipment, both in the station and on the line, is in the order of 90 to 95 per cent of the strength under impulse or, as commonly called, lightning voltages. Referring to Figures 6, 7, and 8, it is noted for suspension insulators, apparatus insulators, and bushings, the positive switching surge strength appears to be only 5 to 10 per cent higher than the crest of the 60-cycle flashover. This would seem to indicate that the switching surge strength, of the pieces of equipment reported in the paper, and having air insulation in the breakdown path, is about midway between the full-wave impulse and the 60-cycle crest flashover values. For such equipment the data presented seem to indicate that the breakdown strength is 5 to 10 per cent lower than the full-wave impulse, and the 60-cycle breakdown 5 to 10 per cent below the switching surge breakdown. However, for oil and oil pressboard as used in equipment such as transformers and the like, the switching surge voltage breakdown is shown some 150 per cent greater for switching surge voltages than on 60-cycle crest. This indeed seems fortunate, if true, as it seems to insure a greater factor of safety in the internal insulation of the apparatus itself than in air-insulated equipment.

Contrary to the generally accepted opinion in the past that impulse flashover of air insulation, such as of insulators, bushings, and rod gaps, is practically unaffected by moisture, the authors show reductions in the order of 10 to 15 per cent, but further state that the reductions are about the same order for switching surges and for lightning or impulses. If this situation holds true throughout the general range of air insulation used on high-voltage transmission systems, it certainly should be given consideration in lightning arrester application.

The subject of contamination in the atmosphere affecting the flashover values of insulaton has been touched on and the general conclusion reached that where the duration of the surge exceeds approximately 1,000 microseconds, there is a pronounced reduction in the flashover. While such contaminated conditions are referred to as "unusual" in the paper, they undoubtedly will become more frequent in the future, although they may not constitute the majority of situations. Quite recently we have adopted the practice of overinsulating, so to speak, the upper end of certain high-voltage bushings as a safeguard against service flashover, due to atmospheric conditions which might be called not perfectly clean. However, it is believed that with the increased extent of electric power systems today and with the growth of chemical industries and industrial plants, what used to be termed "unusual" conditions cannot be passed off so lightly in our standardization work and certainly not in our insulation applications.

Now that the problem of controlling natural lightning on electric power systems has yielded data on which practical equipment can be built and protected within reasonable limits, it is highly desirable that this question of switching surge voltage be further investigated. The very fine paper by Bellaschi and Rademacher, bringing together many of the isolated pieces of work on this subject and their own reported data, should be most helpful in carrying this study through to a conclusion.

I. W. GROSS (F '45)

(Electrical research engineer, American Gas and Electric Service Corporation, New York, N. Y.)

Telephone Inventor

To the Editor:

In the March issue of *ELECTRICAL ENGINEERING* I noticed an article "How Bell Invented the Telephone," the same being a reprint of an article by Thomas A. Watson, AIEE *PROCEEDINGS*, volume 34, number 8, August 1915, pages 1503–13.

I think you people would be interested in reading a publication by Paul Latzky entitled, "Fighting the Octopus." At the time Latzky was collecting his data for this publication, I was employed as an engineer with the Kellogg Switchboard and Supply Company of Chicago, Ill., at that time the largest independent manufacturer of telephone equipment in the country. Prior to going with the Kellogg Company I was with the Western Electric Company in Chicago. I later was with the Dean Electric Company at Elyria, Ohio, and had charge of the manufacturing and installation work, as well as being a power engineer. At that time, the independent system for the city of Detroit, Mich., was built under my supervision.

Without going into any further detail it will suffice to say that I have had many years of experience in the very early days on the common battery switchboard and relating apparatus, and I am quite familiar with the development of the telephone.

I have always been satisfied in my mind that Bell did not invent the telephone, but that the same was invented by Elisha Gray. In any event, so far as anything practical is concerned, Bell did not invent it, as it was the carbon transmitter of Edison and Berliner that made the telephone possible, and the Audion invented by Doctor DeForest, with whom I was associated at the Western Electric Company for a time, which made long distance telephony possible.

I believe in giving credit where credit is due.

A. D. T. LIBBY (A '04)

(Patent attorney, Newark, N. J.)

Submarine Cable

To the Editor:

Referring to *ELECTRICAL ENGINEERING*, February 1947, page 201, there is a slight misconception which appears in the article, "Submarine Telephone Repeater." It is stated that the cable is similar to the Anglo-Irish cable, except that the insulation is polythene instead of air. Actually, the insulation of the Anglo-Irish cable is paragutta.

M. C. TIMMS (M '27)

(Production manager, Submarine Cables, Ltd., Telcon Works, Greenwich, London, England)

Wagner Act

To the Editor:

I have read and reread the membership opinion questionnaire on the Wagner Act and have become convinced that this questionnaire is in the same class with the old one "Have you quit beating your wife?" The only options offered are complete inclusion or complete exemption so far as the Wagner Act is concerned.

In my opinion engineers should be free to choose between affiliation with a union, organization of their own group to function legally as a union, or affiliation with no such group. Those who wish to join an existing union or to form their own organization should have the protection of all unfair labor practice legislation in the books. In other words, engineers have the same right to legal protection, and in some cases the same need of it, as ditch diggers or lathe operators; but when they choose to remain unorganized they should not have this legal protection rammed down their throats.

It seems to me that another poll would be in order wherein this third alternative would be offered.

I am also at a loss to know exactly what my status is under question 2. We of the engineering faculty have part of the say as to who shall be hired and who shall be promoted on the faculty. To that extent, we are supervisors. On the other hand, in the hierarchy we are on the instruction staff and not in the supervising staff. We certainly do not fit under the classification of consultant.

W. B. SHEPPERD (M '43)

(Associate professor of electrical engineering, Oklahoma Agricultural and Mechanical College, Stillwater)

NEW BOOKS • • •

"Tables of Integrals and Other Mathematical Data." A synopsis of compact results, this book includes both fundamental and advanced definitions, identities, integrals, derivatives, and numerical tables of algebraic, trigonometric, exponential, logarithmic, hyperbolic, elliptic, Bessel, and other functions. No derivations are included, but a reference list of sources is given. By Herbert Bristol Dwight (F '26). The Macmillan Company, New York, N. Y., 1947, 250 pages, cloth bound, $5^1/_2$ by $8^1/_4$ inches, $2.50.

"Van Nostrand's Scientific Encyclopedia." Second edition. A collection of brief items on such widely varied subjects as aeronautics, astronomy, botany, chemical engineering, chemistry, civil engineering, electrical engineering, electronics and radio, geology, mathematics, mechanical engineering, medicine, metallurgy, meteorology, minerology, navigation, photography, physics, statistics, and zoology. The entire book is arranged in alphabetical order by subject with liberal cross indexing. Among the contributing editors is L. R. Quarles (M '45); and among the consulting editors are Erich Hausmann (F '18) and John R. Ragazzini (A '33). D. Van Nostrand Company, Inc., New York, N. Y., 1947, 1600 pages, cloth bound, illustrated, 7 by $10^1/_4$ inches, $12.00.

The following new books are among those recently received at the Engineering Societies Library. Unless otherwise specified, books listed have been presented by the publishers. The Institute assumes no responsibility for statements made in the following summaries, information for which is taken from the prefaces of the books in question.

GALVANIZING HANDBOOK. By J. R. Daesen. Reinhold Publishing Corporation, New York, N. Y., 1946. 166 pages, illustrated, diagrams, charts, tables, $10^1/_4$ by 7 inches, cloth, $5.25. The basic principles involved in the hot dip galvanizing of iron and steel are presented graphically, with photographic examples (mainly microphotographs) to demonstrate the nature and cause of both satisfactory and defective work. Particular attention is paid to the preparation of the surface to be covered and to the proper control of the galvanizing procedure. The final chapter deals with hot dip coatings with other metals than zinc. In addition to the chapter references a brief bibliography on hot tinning is appended.

FUNDAMENTALS OF PLASTICS. Edited by H. M. Richardson and J. W. Wilson. McGraw-Hill Book Company, Inc., New York, N. Y., and London, England, 1946. 483 pages, illustrated, diagrams, charts, tables, 9 by $5^3/_4$ inches, cloth, $5. The purpose of this text is to give students a broad view of the plastics industry that will serve as a background for more detailed study. Of the four parts, the first deals with certain fundamentals regarding the relationship of chemical structure to physical properties. The second discusses the six classes of plastics, devoting a chapter to each major group. The third section covers the commercial methods used in the manufacture of plastic products; and the last section deals with the evaluation of plastics, including their measurement and manufacturing control.

INSTITUTE OF PETROLEUM ELECTRICAL CODE. Institute of Petroleum, Manson House, 26 Portland Place, London, W. 1, England, 1946. 77 pages, tables, $8^1/_2$ by $5^1/_2$ inches, paper, *5s*. The definitions, rules, and code schedules presented in this publication are issued provisionally with a view to experience being gained and in anticipation of reports in regard to the practical application of the code in industry. Special topics covered are the problems of dangerous atmospheres and the avoidance of fire arising from lighting, static, and other electrical causes. It also covers flexible cables for use in dangerous areas.

DRAKE'S CYCLOPEDIA OF RADIO AND ELECTRONICS, A REFERENCE AND INSTRUCTION BOOK. Twelfth edition. By H. P. Manly and L. O. Gorder. Frederick J. Drake and Company, Chicago, Ill., 1946. No pagination, illustrated, diagrams, charts, tables, 9 by $5^3/_4$ inches, cloth, $6. The definitions or descriptions in this practical volume range from single lines to several pages of text depending on the simplicity or complexity of the topic. Mathematical explanations have been held to the necessary minimum, but free use has been made of illustrative sketches and diagrams. Considerably revised throughout, the major additions of new material are in the fields of hyper frequencies or microwaves, in industrial electronics, and in the material on tubes.

DECIBEL NOTATION, ITS APPLICATION TO RADIO AND ACOUSTICS. By V. V. L. Rao. Chemical Publishing Company, Brooklyn and New York, N. Y., 1946. 179 pages, diagrams, charts, tables, $8^3/_4$ by $5^1/_2$ inches, cloth, $3.75. This book explains in detail the origin and development of decibel notation and describes a wide range of applications, with special reference to radio engineering and acoustics. Among the topics surveyed are the logarithmic unit, zero levels and level signs, decibel meter and decibel graphs, sound levels and phon calculations. Since the book was originally published in India, the terminology is English rather than American, but the differences are few.

COMMUNICATION THROUGH THE AGES, FROM SIGN LANGUAGE TO TELEVISION. By A. Still. Murray Hill Books, New York, N. Y., and Toronto, Ontario, Canada, 1946. 201 pages, illustrated, diagrams, $8^1/_2$ by $5^1/_2$ inches, cloth, $2.75. From tribal drums and smoke signals to radiotelephony and television the author traces the development of the art and science of communication. In addition to the accepted and scientifically valid methods discussed, there are also interesting sidelights on various supposed or projected methods varying from the unsanctioned to the supernatural, with a final brief discussion of telepathy. Footnote references point to further reading on many topics.

STORY OF THE ENGINEERS, 1800–1945. By J. B. Jefferys. Lawrence and Wishart Ltd., 81 Chancery Lane, London, W. C. 2, England, 1946. 301 pages, illustrated, tables, $8^3/_4$ by $5^1/_2$ inches, cloth, *10s*/*6d*. This book, essentially a history of the Amalgamated Engineering Union in Great Britain, describes the development of the engineering trades from the beginnings of the industrial revolution to the present time and the efforts of the skilled workmen to better their wages and conditions of work by the trade union system. The industrial relations aspects are emphasized, and the activities of the union, of smaller groups, and of individuals are discussed in considerable detail.

STEAM POWER STATIONS. Third edition. By G. A. Gaffert. McGraw-Hill Book Company, Inc., New York, N. Y., and London, England, 1946. 613 pages, illustrated, diagrams charts, tables, 9 by 6 inches, cloth, $5.50. Steam power plant machinery is covered from the standpoint of construction of the various types of equipment, their performance characteristics, economics, and integration in the complete plant. The new edition of this standard textbook has been revised, and includes recent information on modern equipment, such as steam turbines, condensing equipment, steam generating units, and mercury-steam installations. The material has been strictly confined to the mechanical engineering features, with emphasis on design and construction.

SPEEDLIGHTS, CONSTRUCTION AND USE. By A. Palme. American Photographic Publishing Company, Boston, Mass., 1946. 128 pages, illustrated, diagrams, charts, tables, 8 by $5^{1}/_{4}$ inches, cloth, \$2.50. The "speedlight" is a device for high-speed photography which utilizes the discharge of a charged electric capacitor through a transparent tube to cause a contained gas to fluoresce momentarily to high brilliance. This book describes the necessary equipment, the construction and use of speedlights, with particular attention to a simplified type for home assembly. A brief history of high-speed photography is given, and there is a bibliography.

ELECTRIC POWER EQUIPMENT. Third edition. By J. G. Tarboux. McGraw-Hill Book Company, Inc., New York, N. Y., and London, England, 1946. 493 pages, illustrated, diagrams, charts, tables, $8^{1}/_{2}$ by $5^{1}/_{4}$ inches, cloth, \$6. The object of this book is to present a condensed but comprehensive survey of the entire field of electric power equipment to be used as a textbook by electrical engineering students. In addition to the material on generating equipment, circuit layouts, meters and measurements, switching equipment, transmission and distribution systems, the book briefly covers power resources, prime movers, loads and load graphs, and the economics of electrical service. The necessary revision has been made in this edition to conform with current practice in the field.

DIRECT AND ALTERNATING CURRENTS. THEORY AND MACHINERY. Third edition. By E. A. Loew. McGraw-Hill Book Company, Inc., New York, N. Y., and London, England, 1946. 748 pages, illustrated, diagrams, charts, tables, $8^{1}/_{2}$ by $5^{1}/_{4}$ inches, cloth, \$5. Stressing fundamental principles rather than factual information, this book treats the theory of the electric circuit in considerable detail. The laws and principles necessary to an understanding of the performance of electric machines are also thoroughly covered. Alternating circuit theory is discussed largely in terms of vectors. The final chapter deals with electron tubes and rectifiers. The book has been revised in the light of recent advances and for more efficient use by the student.

EXAMINATION OF INDUSTRIAL MEASUREMENTS. By J. W. Dudley, Jr. McGraw-Hill Book Company, Inc., New York, N. Y., and London, England, 1946. 113 pages, charts, maps, tables, $8^{1}/_{2}$ by $5^{1}/_{2}$ inches, cloth, \$2. This book acquaints engineers with simple and adaptable statistical techniques for the detection of variation in industrial products. Important types of data which reveal causes of variation are discussed, and effective methods for collecting, analyzing, and presenting them are explained. With special emphasis on broad industrial application, the book provides simple tools for constructing control charts, making quartile analyses, and analyzing limitations of data curves. Practical examples are given which also illustrate how reliable data can be distinguished from erratic data.

JOB EVALUATION. By F. H. Johnson, R. W. Boise, Jr., and D. Pratt. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1946. 288 pages, diagrams, charts, tables, $8^{1}/_{2}$ by $5^{1}/_{2}$ inches, cloth, \$3.75. This book is designed to explain how a job evaluation plan functions under actual operating conditions. The first part of the book demonstrates the recommended procedures for establishing the plan, evaluating the jobs, and estimating the cost of the program in terms of increased payroll. Succeeding chapters discuss the methods for assigning workers to the jobs and maintaining the plan in efficient operation. There is a bibliography.

Industrial Relations Monograph Number 12, UNIONIZATION OF PROFESSIONAL ENGINEERS AND CHEMISTS, by H. R. Northrup, 52 pages, \$1.50. Industrial Relations Monograph Number 13, RECONVERSION IN INDUSTRIAL RELATIONS, by B. M. Stewart and W. J. Couper, 72 pages, \$1.75. Industrial Relations Counselors, New York, N. Y., 1946, $9^{1}/_{4}$ by 6 inches, paper. Number 12 of this series of studies examines the union movement among engineers and chemists of professional status. Existing unions, the reasons for unionization, the attitude of the professional societies, labor relations board decisions, and collective bargaining activities are discussed in a brief, factual manner. Number 13 takes up the human aspect of reconversion, evaluating the wartime gains and losses in industrial relations, setting forth some of the pressing current problems, and discussing management attitudes and broad matters of policy.

INDUSTRIAL PRODUCTION ILLUSTRATION FOR STUDENTS, DRAFTSMEN AND ILLUSTRATORS. Second edition. By R. P. Hoelscher, C. H. Springer and R. F. Pohle. McGraw-Hill Book Company, Inc., New York, N. Y., and London, England, 1946. 243 pages, illustrated, diagrams, 11 by $8^{1}/_{2}$ inches, cloth, \$4.50. The entire range of pictorial drawing is covered from both the theoretical and practical points of view. Both freehand and instrumental layouts are dealt with, and all procedures are explained and illustrated by breakdown sketches showing step-by-step construction. The new edition includes applications in aircraft and other industries, material of three point perspective has been added, and there is a new chapter on available equipment and special methods. A list of descriptive motion pictures and film strips is correlated with the text material.

HOW TO ORGANIZE AND MANAGE A SMALL BUSINESS. By N. Black. University of Oklahoma Press, Norman, Okla., 1946. 367 pages, charts, tables, $8^{1}/_{4}$ by $5^{1}/_{2}$ inches, cloth, \$3. The reader is taken point by point through the problems, planning, decision, and action of small-business organization and management. Modern management methods are described, and techniques are explained for forecasting and preventing mistakes by the use of business ratio and percentage guides. Important features of the book are the emphasis on effective study of business fundamentals, and the discussion of methods necessary for adequate price-setting. Illustrative examples of particular types of small businesses are freely used.

AMERICAN INDUSTRIES SERIES. Number 4—ALUMINUM INDUSTRY by S. V. Malcuit, 36 pages. No. 5—PLASTICS INDUSTRY by B. L. Crandall, 36 pages. No. 6—REFRIGERATION INDUSTRY by D. C. Choate, 32 pages. Bellman Publishing Company, Boston, Mass., 1946. Illustrated, tables, 9 by 6 inches, paper, \$1 each. Three of a series of pamphlets intended to present an over-all account of a large number of basic American industries, as well as information about the "jobs" that comprise these industries. The job information part provides material on personal qualifications and scholastic training needed, remuneration, chances for advancement, possibilities for both men and women in the industry, and a statement of advantages and disadvantages. A feature of each pamphlet is the analytical index of occupations in the particular industry, with brief descriptions farther along of the duties of the various jobs listed.

MANUFACTURING PROCESSES. Second edition. By M. L. Begeman. John Wiley and Sons, New York, N. Y.; Chapman and Hall, London, England, 1947. 626 pages, illustrated, diagrams, charts, tables, $8^{1}/_{2}$ by $5^{1}/_{2}$ inches, cloth, \$5. Beginning with foundry practice and ending with grinding wheels and abrasives, this volume presents the technical fundamentals of the important manufacturing processes, discusses engineering materials, and describes the modern machine tools necessary for processing these materials. New chapters in the present revision deal with special casting methods, powder metallurgy, hot forming, and cold forming of metals. The material on welding and plastic molding has been extensively revised. There is also a chapter on inspection and gauging practice.

CERAMIC WHITEWARES, HISTORY, TECHNOLOGY AND APPLICATIONS. By R. Newcomb, Jr. Pitman Publishing Corporation, New York, N. Y., and Chicago, Ill., 1947. 313 pages, illustrated, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, \$5. The production of all types of "ceramic whitewares" (pottery, porcelain, and china) is described in detail, including the raw materials, test methods, forming, drying, firing, and decorating. The second section covers the properties of the fired ware, and discusses the methods of utilizing these characteristics in a variety of products for use in the home, construction work, the electrical, and other industries. Chiefly valuable to the manufacturer and the practical man who is concerned with the engineering properties and uses of ceramics, the book is intended for a wider field and includes a historical introduction showing the development of the art.

MAGNESIUM FABRICATION. By L. B. Harkins. Pitman Publishing Corporation, New York, N. Y., and Chicago, Ill., 1947. 149 pages, illustrated, diagrams, charts, tables, $9^{1}/_{4}$ by 6 inches, cloth, \$2.75. This practical handbook presents authoritative data for all phases of the fabrication of magnesium-alloy sheet, extrusions, and tubing into the finished product. Important topics covered include machining, forming, heat treating, welding, joining, surface finishing, and protection. The techniques peculiar to magnesium are emphasized, together with notes on fire control and protection against corrosion. The major producers and fabricators in the industry are listed.

APPLIED ATOMIC POWER. By E. S. C. Smith, A. H. Fox, R. T. Sawyer, H. R. Austin. Prentice-Hall, New York, N. Y., 1946. 227 pages, illustrated, diagrams, charts, maps, tables, $9^{1}/_{4}$ by 6 inches, cloth, \$4. The purpose of this book is to explain in relatively simple language just what atomic power is, and to discuss how that power may be applied to our everyday needs and purposes. Other topics are effectively covered, such as: the mineral uranium, the phenomenon of fission, and the problems encountered in the production of plutonium.

PAMPHLETS ● ● ●

National Electrical Code (National Board of Fire Underwriters Pamphlet 70). American Standards Association, 70 East 45th Street, New York 17, N. Y.

Proceedings of the Second Industrial Waste Conference—Bulletin 60. Engineering Extension Department, Purdue University, Lafayette, Ind., 183 pages.

Symposium on Atmospheric Weathering of Corrosion-Resistant Steels. American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa., 92 pages, \$1.50.

Report on Standard Samples for Spectrochemical Analysis, 1947 (Technical Bulletin No. 41-B). American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa., 28 pages, \$1.25.

American Safety Standards. A catalogue containing a list of approximately 200 standards covering safety and industrial health, with brief descriptions of each is available from the American Standards Association, 70 East 45th street, New York 17, N. Y., 20 pages.

Tentative Specifications for Corrosion-Resisting Chromium and Chromium-Nickel Steel Welding Electrodes (American Welding Society designation: A5.4-46T; American Society for Testing Materials designation: A298-46T). Copies of this 13-page 6-by-9-inch booklet may be obtained at 25 cents each from the American Welding Society, 33 West 39 Street, New York 18, N. Y., or from the American Society for Testing Materials, 1916 Race Street, Philadelphia 3, Pa.

Index of RCA Technical Papers, Volume I and II(a). These pamphlets are available from the RCA Laboratories division of the Radio Corporation of America, Princeton, N. J. on request. Volume I covers papers published from 1919–45, and volume II(a) covers papers published in 1946.